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AUTHOR Demirjian, Y. A.
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ABSTRACT

This document reports the development and operation of a country-wide wastewater treatment program. The program was designed to treat liquid wastewater by biological treatment in aerated lagoons, store it, and then spray irrigate on crop farmland during the growing season. The text discusses the physical design of the system, agricultural aspects, monitoring, research, and economics. References and discussion of the current status of the project are included. (CS)

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DESIGN SEMINAR

FOR

LAND TREATMENT OF MUNICIPAL WASTEWATER EFFLUENTS

PREPARED
FOR
UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
TECHNOLOGY TRANSFER PROGRAM

MUSKEGON COUNTY WASTEWATER MANAGEMENT SYSTEM

PREPARED
BY
Y. A. DEMIRJIAN, Ph.D., MUSKEGON COUNTY,
MUSKEGON, MICHIGAN

SE 023 885

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INTRODUCTION

The polluted conditions of streams and lakes in the county by the industrial and domestic effluent discharges created the necessity of the Muskegon System. Over the years, increased effluent discharges plagued the streams and the lakes, and the value of the surface waters for recreational purposes was in peril. The county's Metropolitan Planning Commission commenced to review and appraise alternate plans for treating the county's wastewater effluents. The final recommendation was that it is economical to treat wastewater in lagoons; followed by land treatment (irrigation) for further purification. The County submitted the final plans of land treatment of wastewater to the federal and state agencies for approval and financial aid; the wastewater project was approved and funded. An up-to-date estimated cost of the project is about $42 million; of which all but $16 million was funded by state and federal grants. There is also $1.935 million for research and development; 75% federally funded and 25% county. Financing of the $16 million portion was made by a twenty-year bond issue. Operations and maintenance expenses are supported by fee agreement with the local municipalities and industrial user's based on discharged effluent volume; provided the County makes the necessary tie-ins (sewer points for collection).

At the present time the largest spray irrigation land treatment facility in operation in the United States is the Muskegon County Wastewater Management System. The Muskegon County Wastewater Management System is a county-wide wastewater treatment

program. Municipal and industrial effluents are collected from throughout the county, then transmitted into the central treatment plant. Here the wastewater is treated and further purified using the living filter concept.

The system has replaced three existing municipal treatment facilities with a total flow of 10 MGD and eliminated the direct discharge of four industrial plants with a combined flow of 18 MGD.

The design objectives of the Muskegon System are to treat domestic and industrial effluent wastewater adequately and comply with local, state and federal discharge requirements for resource management, development of the local economy, and provide environmental protection. More specifically, the Muskegon System is designed to prevent any significant direct discharge of municipal or industrial wastewater to the shoreline lakes. The elimination of direct discharges of liquid waste will result in improvements in water quality and promote ecoromic and recreational development in the county.

The system is designed to reduce the typical pollutants in the mixture of domestic, commercial and industrial wastes as follows[1]:

Item	Muskegon-Mona Lake Influent	Whitehall-Montague Influent	Effluent	Effective Removal (%)
BOD-mg/l	250	500	4	98-99
Suspended Solids-mg/l	250	1000	4	98-99
Phosphorus-mg/l	5	3	0.5	83-90
Nitrogen (Total N)-mg/l	20	40		
Ammonia-N-mg/l			0.5	97-98
Nitrate-N-mg/l			5.0	75-87
Coliform Bacteria #/100 ml	$2\text{-}20\text{x}10^6$	$2\text{-}20\text{x}10^6$	0	100%
Pathogenic Viruses	Known to be present in undefined concentration	Known to be present in undefined concentration	0	100%

Corn is the primary crop in the Muskegon County System. Corn will utilize the nutrients from the wastewater and will refurbish the soil as a filter[2].

II. DEVELOPMENT OF DESIGN CRITERIA

A. Geographic Location

Muskegon County is located on the eastern shore of Lake Michigan approximately 115 miles north of its southern tip. The Muskegon County Wastewater Management System is located 15 miles east of the lake shore and 10 miles north of the county's southern boundary. Figure 1 shows the location of the treatment site in the county.

B. Climatological

Rainfall and temperature are greatly influenced by Lake Michigan. Precipatation is moderate and averages about 30 inches per year. Snowfall averages around 86 inches, most of which occurs during the period of December - January. The average maximum temperature is recorded in July at 80.3°F with the average minimum in January at 17.6°F. The mean average annual temperature for the area is 47.2°F. The average frost-free period ranges from 160 - 170 days.

C. Site Selection

There are many interrelated factors that were considered in the present site selection. Soil type and topography were prime considerations. The four (4) major soil types on the Muskegon site are Roscommon, Rubicon, Au Gres, and Granby. Each of these soil types are sandy except Granby which is a sandy loam. They are all very permeable to water. The high permeability reduces the amount of land required for irrigation purposes. The site is located on a flat outwash plain. The land contour has slopes in 0-6% range. These low slopes eliminate any run-off or erosion from the irrigation area.

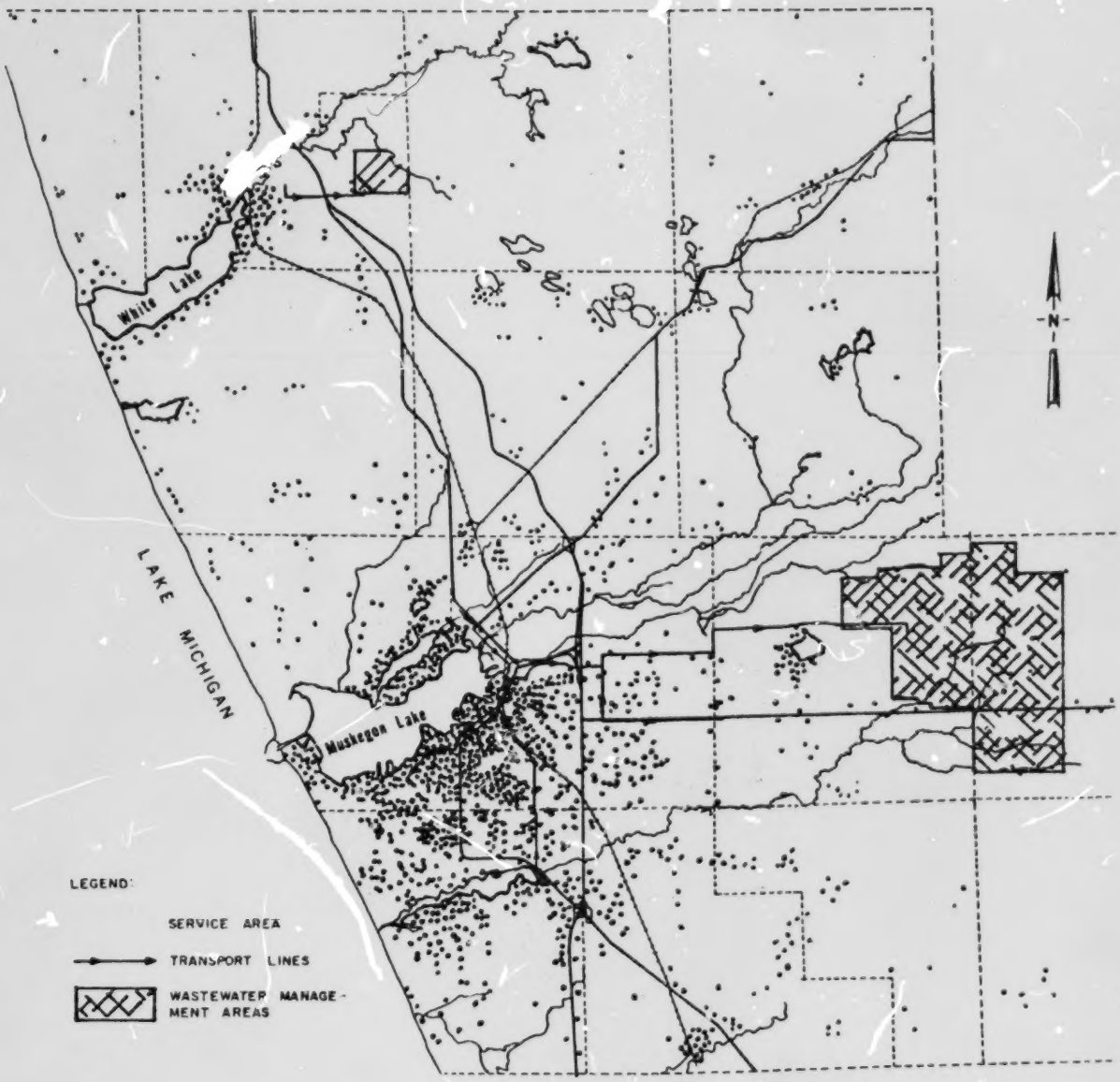


FIGURE 1

SITE LOCATION

Considerations were given to availability of land, price of land, and relocation of 200 residents. Since land treatment requires a larger land area than other conventional forms of wastewater treatment, land availability and cost are important factors. The location should be reasonably close to the collection system. At the Muskegon site, the wastewater is transported eleven (11) miles from the main pumping station through a 66-inch force-main to the treatment site. Over 10,000 acres of land are required for treatment, storage, irrigation and buffer areas. The lack of nutrients and moisture holding capacity of the soil makes the land unsuitable for most agricultural purposes. This fact, in combination with the factor of a low population density, helped keep the land cost down.

Total land, dwellings and legal	$5,371,614.17
Total relocation expense and other legal	1,165,660.70
	$6,537,274.87

In developing the design criteria native vegetation, wildlife and multiple use factors were also considered. The vegetation is important from the land clearing point of view. At the Muskegon site approximately 50% of the land area was scrub black oak and had to be cleared. Other areas were scattered with scotch pine and jack pine plantations, aspen, ash, lowland hardwoods, open grassland and white pine and oak forests. The land clearing and construction can have an impact upon the wildlife population and should be considered. Prior to land clearing, there were small populations of whitetail deer, cottontail rabbits, ruffed grouse and ring-necked pheasant. Since that time waterfowl and shoreline birds have appeared in large numbers. Increases in the populations of the other wildlife species are expected also, since food and cover are readily available. The final consideration in the design of the site is multiple land use. At the Muskegon site, for example, a solid waste site was constructed. Since the site has total groundwater control, leachate from the solid waste site can be collected, pretreated if necessary and pumped to the large storage lagoons. Other multiple usages could include recreational facilities, wildlife management through controlled hunting, and the building of a nuclear power generating plant by Consumers Power at the site using the lagoon water for supplementary cooling purposes.

III. PHYSICAL DESIGN OF THE SYSTEM

A. Design Flow

The flow projections are estimated on population growth and service area extensions, development of industrial and commercial parks, the present industrial activity flows that are in service now, and connecting the existing industrial flows that are discharging into the surface waters presently. The present and projected population growth and service area growth are as follows:

1972 Estimate*		1992 Design* Estimate	
Population	Service Area	Population	Service Area
140,000	125,000	182,000	161,000

*This population information was taken from the Muskegon County Planning Commission and 1970 preliminary U.S. census information by community.

At the present, major municipal contributors are the City of Muskegon, Muskegon Heights, North Muskegon and the City of Roosevelt Park. Average unit flow rate from these domestic sources is 90 gpcd and a peak rate of 200 gpcd. The major industrial contributors are S. D. Warren Co. and Ott Chemical Co. The following table (table 1), lists up-to-date wastewater effluent contributors to the system and the average daily flow of each contributor. S. D. Warren papermill is the largest contributor with 16 MGD; it is a Kraft mill operation.

TABLE 1

	MGD (Current)
City of Muskegon	8.7
S. D. Warren Paper Mill	16.0
Teledyne Continental Motors	NIS
City of Muskegon Heights	1.4
City of Norton Shores	0.56
City of North Muskegon	0.355
City of Roosevelt Park	0.6
Laketon Township	NIS
Fruitport Township	NIS
Egelston Township	NIS
Dalton Township	NIS
Muskegon Township	NIS
Ott Chemical	0.9
Current Total Flow	27.56 MGD

(Note: NIS - Not in service at the present time)

Table 2 shows the summary of the 1992 estimated system flows and the relative contributors and the source areas of the contributors.

TABLE 2*

Muskegon-Mona Lake Area System	Avg. Flow - MGD	Per cent of Total	Peak Flow - MGD
Domestic Flows	16.04	37	40.0
Mixed Industrial and Commercial Flows	4.62	11	11.5
Special Industrial Flows	13.50	34	17.2
Special Development Areas	7.84	18	19.6
	42.0	100	88.3

*These estimated flow rates were taken from Bauer Engineering of Chicago; preliminary studies of Muskegon Project.

In design considerations it is essential to know the characteristics of the effluent wastewater as well as the hydraulic loading. From land treatment design point of view, from the wastewater loading and character the pretreatment requirements are evaluated with respect to storage lagoon loading tolerance (lagoon dynamics) and the management of living filter processes; particularly looking from nutrient point of view, nitrogen and phosphorus. It is a well known fact that nitrogen removal by conventional treatment is expensive, and there is no reasonable, efficient removal process available yet. Nitrogen is one of the most important factors in considering application rate of effluent on land for maximum crop utilization. The other important parameter to be considered is the phosphorus levels in the applied effluent. Phosphorus plays an important role from the soil conservation point of view and the soil-heavy metal interaction.

B. Wastewater Characteristics

The Muskegon County Wastewater Management System (MCWWMS) is designed to treat combined industrial and domestic liquid wastes. The composition of wastewater is approximately 40% by volume domestic and 60% industrial in origin. The calculated population equivalent (P.E.) of this wastewater is 300,000, and the county's domestic wastewater is 125,000 P.E. This combined industrial and domestic wastewater presents a unique opportunity to study and/or to demonstrate how the wastewater is treated in the Muskegon System. Table 3 shows the MCWWMS effluent wastewater quality[3].

TABLE 3

Wastewater Characteristics
One Year's Average Results

BOD mg/l	220	PO_4^{2-}	mg/l	6.5
pH	7.5	SO_4^{2-}	mg/l	85
Sp. Conductivity umhos	1300	Cl^-	mg/l	175
		Na^+	mg/l	150
Total Solids mg/l	1050	Ca^{2+}	mg/l	70
Suspended Solids mg/l	325	Mg	mg/l	16
Total Volatile Solids mg/l	500	K	mg/l	11
COD mg/l	550	Fe	mg/l	1.25
Total Organic Carbon mg/l	140	Zn	mg/l	0.9
NH_4^+ - N mg/l	9.0	Mn	mg/l	0.25
NO_3/NO_2 - N mg/l	0			

C. Collection, Treatment & Storage

The Muskegon County Wastewater Management System is located on 11,000 acres (4,452 hectares) of sandy land. The delivery of wastewater to the treatment area (farm site) is accomplished by collecting the domestic waste and industrial effluent through a network of force mains, pumping stations, and gravity sewers. There are six pumping stations (lift stations), provided with a total of 13 access points. Figure 2 shows the collection system and transport system. Vertical non-clog sewage pumps are used for the pumping stations. The force mains and gravity sewers are sized with velocities approximating 6 feet per second.

The central pumping station delivers the wastewater from the lift stations to the farm site. This center pumping station, "C" Station, is located in downtown Muskegon; it has a maximum pumping capacity of 56,000 GPM (212 cubic meters/minute). The combined wastewater is then pumped through a 66 inch diameter (1.68 meters) reinforced concrete pipe 11 miles (17.2 kilometers) to the treatment site; Figure 3.

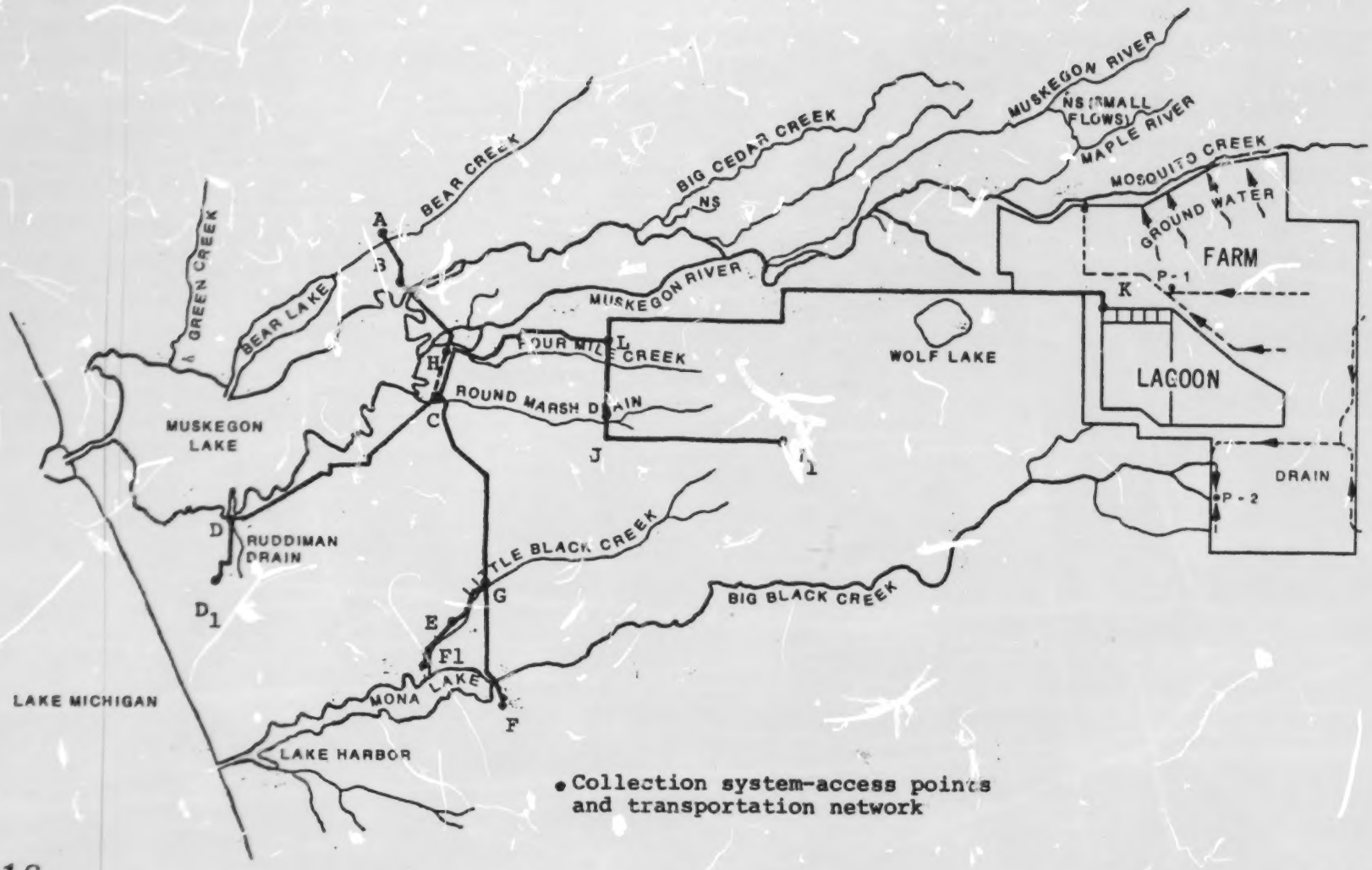
At the farm site the wastewater is treated biologically in three aerated lagoons which are operated either in series or in parallel, depending upon seasonal conditions. Each lagoon is asphalt-cement lined with 8 acres (3.24 hectares) surface area, and each has a holding capacity of 42 mg (0.159 million cubic meters). Each treatment cell is equipped with 12 mechanical floating aerators and six mixers with 1,000 combined horsepower. The treatment wastewater from the aerated lagoons or treatment cells is discharged into two large storage lagoons.

The three biological treatment cells will provide 3 days of retention time at design flow rate of 42 MGD. The water depth in these cells is 15 feet, with a 4 foot freeboard. The cells are concrete lined on the slopes and have a soil-cement lining at the bottom. The floating mechanical surface aerators are rated at a transfer capacity of 2.75 lbs. of oxygen per hour. Each aerator unit is rated at 60 HP and the mixers are rated at 50 HP each.

Each storage lagoon covers an area of 850 acres (344 hectares), or 1,700 (688 hectares) total, with a combined total storage capacity of 5.1 billion gallons (19.3 million cubic meters). At 42 MGD flow, the

FIGURE 2

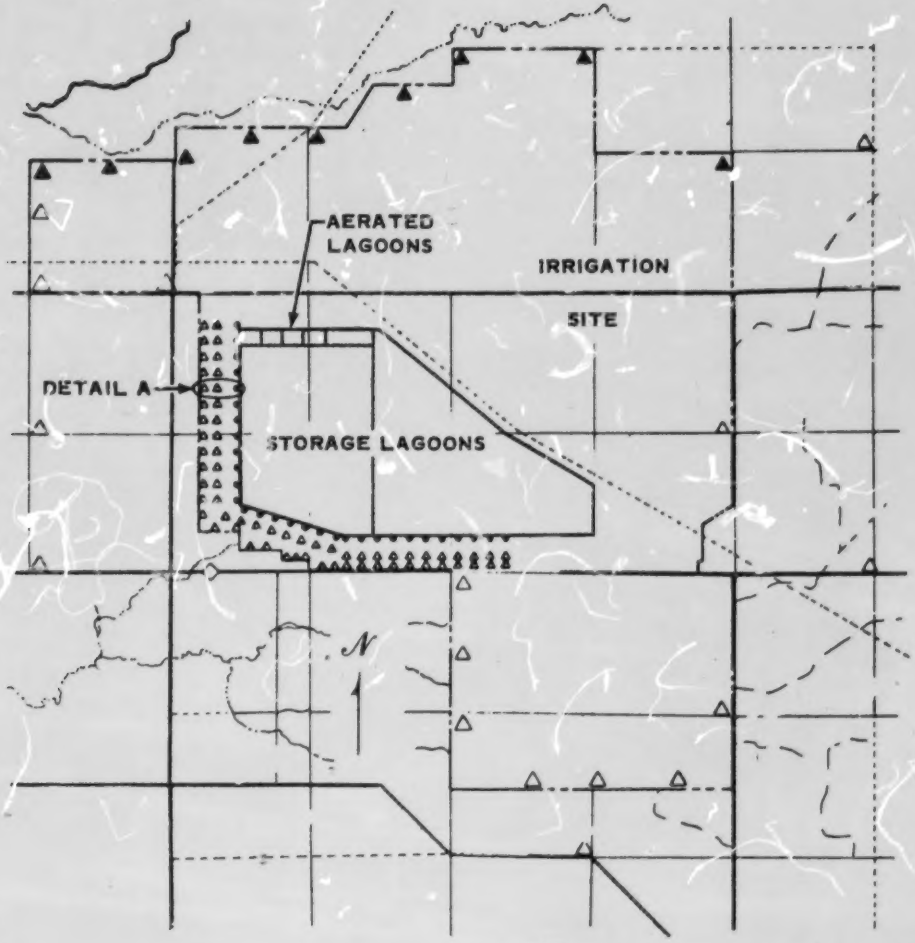
COLLECTION TRANSMISSION SYSTEM

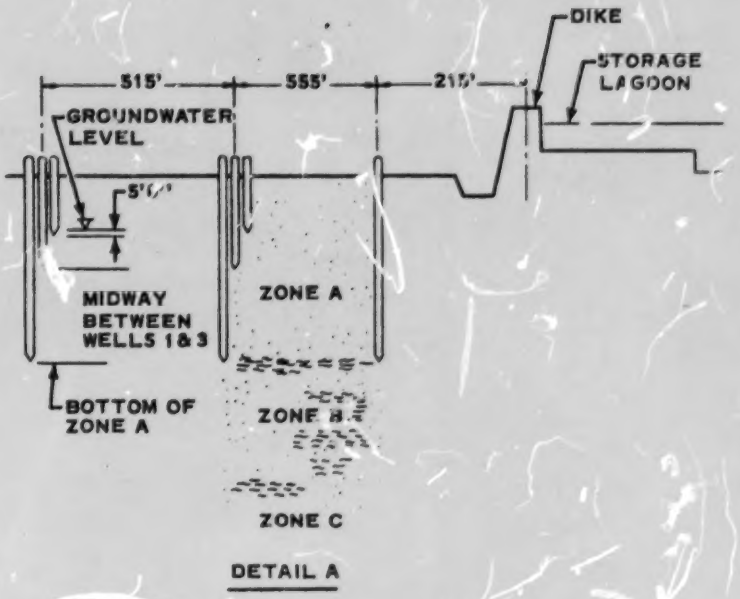


• Collection system-access points and transportation network

FIGURE 3

TREATMENT SITE





LEGEND

- △ THREE WELL CLUSTER AROUND SITE AREA
- ▲ THREE WELL CLUSTER AROUND STORAGE LAGOON
- ⊙ SINGLE WELL AROUND STORAGE LAGOON
- ---- TREATMENT PERFORMANCE STUDIES
- △ SITE BOUNDARY

storage capacity is designed for approximately four months. The storage lagoons are encircled by 15 feet (4.6 meters) high dikes with 200 feet (61 meters) base width. The border strip of the storage lagoons are lined by 8 inches (20 centimeters) impacted clay. The strip is 400 feet (122 meters) wide. Combined dike and strip border provides 600 feet (183 meters) of horizontal filtration. The storage lagoons have a solids storage depth of 2-3 feet, with a water marking depth of 9-12 feet and 3 feet of freeboard. The lagoons have side slopes of 4:1 interior, and 3:1 exterior; the interior slope protection is soil-cement lining. The storage lagoons are surrounded with interception ditches. These ditches are designed to catch seepage water from the storage lagoons and the ground water. Water quality is monitored daily. If the water quality meets the State of Michigan Health Department standards it is pumped into the surface receiving streams. The leachate which seeps to the interception ditch is returned or discharged to the storage lagoon by two pumping stations. One is located on the northeast dike on the east lagoon and the other is located on the south dike on the west lagoon. Both are equipped with 3-75 hp pumps @ 6000 gpm. Each station pumps 8-15 MGD depending on changing hydraulic head of storage lagoon water level. The treatment system is also equipped with a settling lagoon with similar specifications as the aerator lagoons and an outlet lagoon with 14 acres (5.67 hectares) surface area and 12 feet (3.66 meters) depth. The settling lagoon and the outlet lagoon facilities permits the treated wastewater to be discharged directly to the irrigation pumps during high demand periods, by passing the storage lagoons. The gravity flow of the treatment complex provides the flexibility to operate the treatment system in any combination desired. The prolonged retention time of the storage lagoons is beneficial for breaking down the toxic waste and pathogenic bacteria and provides a winter storage area. During the irrigation season, the treated wastewater from the storage lagoons is released into the outlet lagoon (polishing lagoon) and subsequently disinfected by chlorination.

The chlorinator is equipped with two evaporators and each unit chlorinates 6,000 pounds per day, with a total capacity of 12,000 pounds per day @ 14.4 mg/l @ 100 MGD wastewater flow rate; this is the maximum dosage rate. The disinfected effluent is delivered by two channels to the north and south irrigation pumping stations with almost no residual

chlorine remaining. The north channel has a length of 4,300 feet with maximum velocity of 2.5 fps. The minimum residence time is 29 minutes. The south channel has a length of 9,000 feet with maximum velocity of 2.5 fps. The minimum residence time is 63 minutes. The maximum flow rate in each channel is 50 MGD and contact time at maximum flow is 15 minutes. Figure 4 shows the treatment cells, the storage lagoons, irrigation channels, and the surrounding farm site.

D. Irrigation System

The irrigation system is comprised of the following:

1 - Irrigation Pumping Stations
2 - Distribution Pipeline Network
3 - Center Pivot Irrigation Machines
4 - Groundwater and Subsurface Drainage System or Network

The total area within the irrigation circles is 6,000 acres. Total design water balance per year is 42 MGD x 365 days = 15,200 MGD; irrigation season is 8 months or 240 days. Design average weekly application rate is 3.8 inches including rainfall for 8 months of irrigation period.

1 - Pumping Stations: There are two irrigation pumping stations, one for the north irrigation channel and the other for the south irrigation channel. Each pumping station has two manifolds. Table 4 summarizes the pump type and number and the pump rating used for the irrigation system[1].

TABLE 4

STATION/MANIFOLD	PUMPS NO-TYPE	PUMP RATINGS GPM-TDH(ft)	TOTAL CAPACITY(cfs)
1-1	4-Vertical Turbine	3660 @ 198'	33
1-2	4-Vertical Turbine	4275 @ 212'	39
2-1	6-Vertical Turbine	4375 @ 208'	59
2-2	3-Vertical Turbine	1910 @ 162'	13

2 - Irrigation Pressure Pipeline Network: The distribution pipeline network to the irrigation rigs consists of approximately 25 miles of asbestos-cement pipe. The size ranges from 8 inch pipe located at the end of a lateral line to 36 inch pipe which connects directly to the manifolds of the irrigation pumping stations. Strength specifications required transite pipe for pressures not less than 190 psi with 8 feet of cover and Class C bedding. The actual depth of the pipe, however, is only 4-5 feet. The pipeline is hydraulically

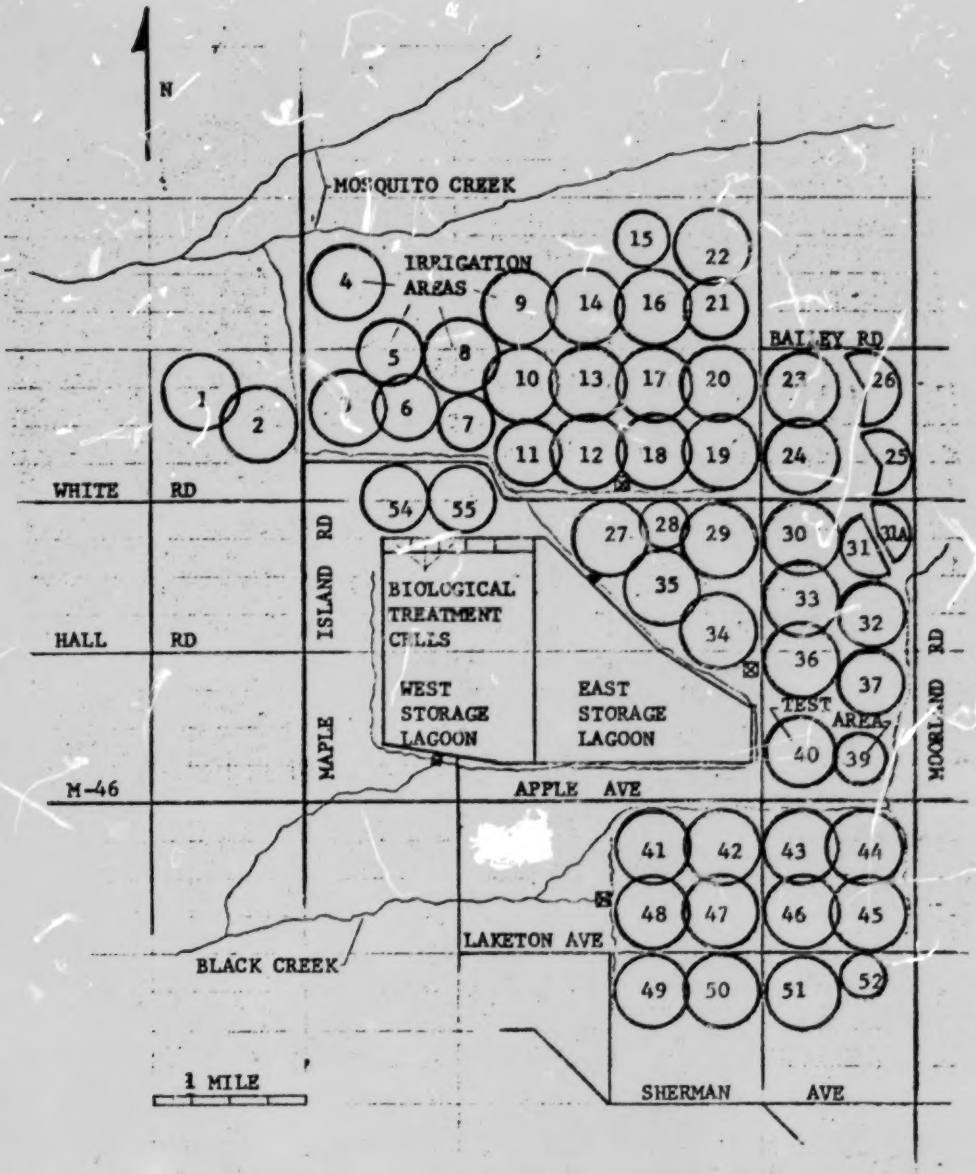


Figure 4 Muskegon County Wastewater Management System No. 1

equipped with air relief valves at the high points and ball valve drains at the low points. The pipelines were pressure tested at 125 psi which is the required maximum operational pressure.

3 - Irrigation Machines: Center pivot spray irrigation machines are used at the Muskegon System. The main pipe structure is supported with a truss type suspension. All the towers are powered by electric motors and are shaft driven. The machines are equipped with rubber tires, 11 x 24 and 14.9 x 24 size tires were specified.

Three inch spray bars are used. The spray nozzles are spaced directly along the length of the spray bars. The nozzle openings are 1/8 to 1/4 inch. The center pivot machines vary in length from 750 feet to 1400 feet, 42 to 142 acres coverage each. The hydraulic capacities of the rigs are up to 3 cfs and the minimum pressure at pivot is 35 psi.

4 - Groundwater Conditions and Subsurface Drainage: Prior to the construction of the Muskegon County Wastewater System, groundwater depths of less than 5 feet were common in extensive sections of the south and east site area. Generally, these depths increase to greater than 25 feet moving north and west across the site. Groundwater inflow occurred primarily along the eastern boundary of the project area and secondarily along a portion of the southern boundary. The main patterns of groundwater outflow was toward Mosquito Creek and Big Black Creek[9]. Subsurface drainage facilities were required for the following reasons[1]:

1) Maintenance of at least 5 feet of free draining aerobic soil for percolation of irrigation water to facilitate biological cleansing and soil adsorption processes.
2) A controlled inward movement of groundwater along site boundaries where private water supplies exist or may be developed by providing a small hydraulic gradient inward toward the site.

On the Muskegon site there are three types of subsurface drainage. They are drainage tiles, drainage wells and natural drainage. This drainage network collects the filtered renovated water and directs it to nearby receiving surface water systems. The drainage system consists of 35 wells, 70 miles of drain tiles, 19 miles of dra...

pipe and 10 miles of ditches. Approximately 500 acres of irrigated areas are drained naturally. See figure 5.

The majority of the irrigation site is drained by drainage tile and ditches. Corrugated polyethylene plastic perforated drain laterals, filtered by nylon socks are spaced from 500 to 1000 feet and are buried from 5 to 8 feet deep. Depth of the tile for effective drainage will vary with soil type. Sandy soils with rapid permeability should be placed at a 4 foot or greater depth, clay soils of a slow permeability at a 2.5 foot depth[10], (most soil types are sandy). The interval between tile laterals should also be determined by soil type and permeability. For sandy soils of rapid permeability a maximum 300 foot interval is recommended for adequate drainage. In organic soils of slow to rapid permeability a range of 50 to 200 foot intervals is used. On clay soils of very slow permeability a range of 30 to 70 foot intervals is recommended[10]. On the Muskegon System most of the drain tile laterals were placed at 500 foot intervals. The reason for this being that field observation and tests indicated that this would be adequate. In the heavier clay soils further field test will have to be made under different hydraulic loadings to determine if additional subsurface drainage must be installed.

The plastic pipe varies in size from 6 to 10 inches. The concrete pipe ranges from 10 to 36 inches in diameter. Perforations in the plastic pipe are 1.5 inches long and 1/16 inch wide. The nylon sock has fiber spaces of 0.45 millimeters. These connect to concrete mainline pipes which carry the drained water to ditches. They in turn discharge to two receiving streams located north and south of the project boundaries.

The north discharge ditch is a gravity flow ditch to Mosquito Creek. Approximately 65% of the irrigated leachate is collected and discharged into this system. In the south there is one drainage pump station which lifts water from the Laketon ditch and discharges it to Black Creek. The Laketon ditch runs north and south and lies west of circle 48. It drains the twelve (12) circles on the south end of the project. The flow ranges from 3 MGD during the winter to 6 MGD in the summer during irrigation. Three - thirty hp, 6500 gpm pumps lift the drainage water to Black Creek.

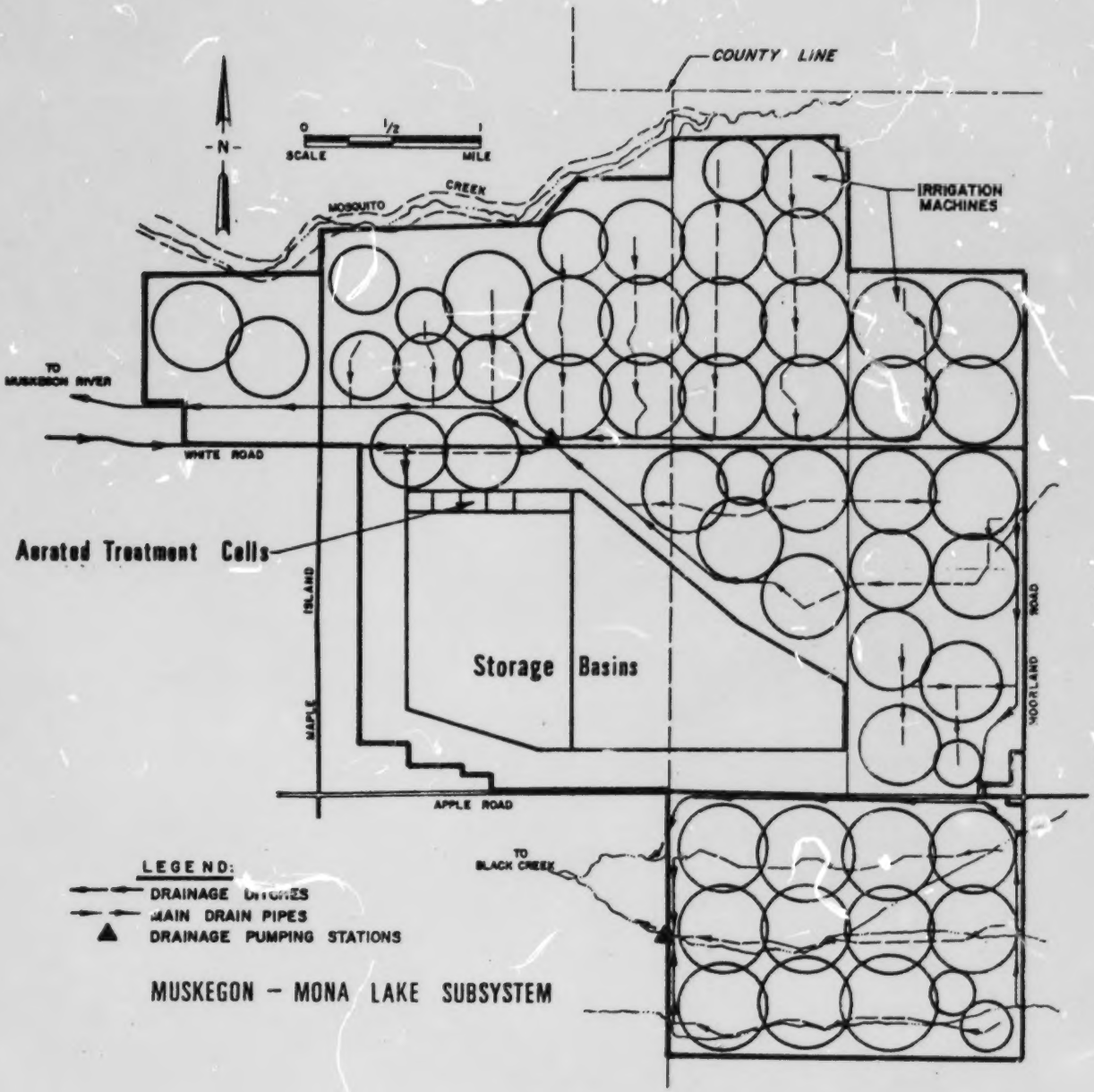


FIGURE 5

DRAINAGE SYSTEM

One section (approximately 400 acres) of irrigated land is drained by wells. These are located primarily in circles 36, 37, 39 and 40. The reason for this is circles 39 and 40 were used as a test site for the proto-type irrigation machines during the pre-construction period. The groundwater supplied a water source for testing purposes prior to receiving wastewater at the site. There are two other areas drained by wells. These are on the west side of treatment lagoons and on the south side of irrigation circles 1 and 2. These two areas are drained by wells because the depth to the groundwater table is such that drainage tiles are not feasible. The wells are equipped with 10 h.p. pumps and level control floats and discharge to plastic (PVC) mainline pipes which transport the pumped water to the drainage ditches.

The remaining irrigated areas, about 500 acres, is drained naturally This takes place along the northern boundary of the irrigated area where the depth to groundwater exceeds 25 feet due to the discharge gradient of the water table to the low-lying Mosquito Creek. This area is not inhabited and, therefore, there is little chance of contaminating a water supply.

E. SOIL CHARACTERISTICS

The disinfected effluent is then spray-irrigated by 54 spray rigs on the farm land. The irrigation land consists of the 6,000 acres surrounding the treatment cells and storage lagoons. The irrigation water application rate is based on soil characteristics and crop untake of nutrients.

1. Soil Type

On the Muskegon site, infiltration rates range from 5" to more than 10" per hour on sandy soil, 2.5" to 10" per hour on loamy soils and 0.02" to 2.5" per hour on clay soil[4]. Soil infiltration characteristics are

a major consideration in the selection of a site for a spray irrigation land treatment system. The major soil types in the Muskegon System as mentioned earlier are Roscommon, Rubicon, Au Gres, Granby and some Nester. Table 5 shows the Muskegon System's major soil types and the hydraulic loading characteristics.

TABLE 5

HYDRAULIC LOADINGS

Soil Types	Water Holding Capacity*		Permeability		Hydrologic Limitation
Roscommon	very low	10	very rapid	10	very severe-requires drainage
Rubicon	very low	10	very rapid	10	irrigate up to 1" slight-per hr or 8"/wk.
Au Gres	very low	10	very rapid	10	severe-requires drainage
Granby	very low	10	very rapid	10	very severe-requires drainage
Nester	high	18-23	slow	.2-.8	very- slow permeability severe requires erosion controls

*inches per 5 ft soil

2. Heavy Metals Assimilation

Investigators have indicated that Ni, Pb, Hg and Cr showed no significant increase in either the grain or leaves of corn between 0 and 180 dry tons/acre application of sludge. Cd and Zn also showed no significant increase in the grain, but significantly higher concentrations of these metals were found in the leaves with increased loadings from 0 to 180 dry tons/acre[6]. Hinesley reported a significant increase in Mn in corn leaves grown on sludge treated soil, but no significant increase in Ca, Mg, Cu, Fe, Ni, or Zn[7].

In the Muskegon project, substantial accumulations for sludge applications are not predicted to happen in the near future. The calculated figures project 10 to 15 years required for adequate amounts of sludge accumulation for land application. The liquid treated waste in general does not contain appreciable amounts of heavy metals which would have detrimental effects on living filter processes. Muskegon effluent shows negligible or very low levels of heavy metals.

3. Assimilation of Dissolved Solids

A soils ability to assimilate dissolved solids is directly related to its cation exchange capacity, C.E.C. A paradox exists here for, on one hand, a soil of high C.E. C. is most desirable for land treatment. This results in maximum nutrient adsorption from the wastewater and maximum renovation. On the other hand, the soil must have a moderate to high permeability if it is to function properly under the high hydraulic loading associated with land treatment. Cation exchange sites are located almost exclusively in the clay fraction of the soil and generally the higher clay content a soil has the slower is its permeability. The ideal situation, therefore, is a soil of high C.E. C. and rapid permeability, but this cannot be found naturally occurring.

The soils of the Muskegon System range from very sandy to very high clay content; however, the majority of land area is composed of sandy or sandy loam rapid permeability soils. Of the many cation exchange reactions which may occur in the soil, one of the most important is that of Na^+ for Ca^{++}. The sodium absorption ratio [$SAR = Na^+/\sqrt{(Ca^{++} + Mg^{++})/2}$] is particularly important in irrigated areas due to the decrease in permeability which will result if Na^+ sufficiently saturates the cation exchange sites of the soil. It is generally accepted that a SAR of 8 or less is considered safe for all agricultural purposes. SAR of the Muskegon effluent is calculated at 3.34 from 1974 storage lagoon data; therefore, no adverse effects from cation exchange of Na^+ for Ca^{++} are anticipated.

4. Crop Uptake of Nutrients

Nitrogen may be one of the most important factors which dictates the overall area requirements and crop selection. The basic processes involved in removing nitrogen from soil are crop assimilation and denitirifcation. There are other factors which must be considered in the mass balance of the nitrogen. These include nitrogen fixation and leaching to groundwater. The nitrogen mass balance in the soil profile is not well defined and fully understood yet. The available mass balance modeling is not adequate and further investigation, field observations and experience are needed in this area. The Muskegon project offers an excellent opportunity for investigation and obtaining the experience to answer some of these questions on the nitrogen mass balance. The following discussion and field observations in Muskegon could offer some information on the nitrogen conditions and effluent application rate limitations.

According to Aldrich, et.al, analysis of 100 bushels of corn yields 90 pounds of nitrogen in the grain and 67 pounds of nitrogen in the stover[8]. Therefore, the total amount of nitrogen assimilated is 157 pounds per acre. In order to calculate the amount of irrigation required to fulfill the nitrogen requirement of 100 bushels/acre of corn, the following assumptions were made:

1 - Nitrogen fixation equals denitrification.
2 - Other major and micro-nutrients available in ample supply.
3 - There is no change in the nitrogen concentration of the soil before and after irrigation.
4 - The average nitrogen concentration of the irrigation water is 6.0 mg/l.
5 - There is no nitrogen lost to the groundwater.

Based on these assumptions and the 157 pounds of nitrogen required by the crop, the total hydraulic loading would amount to 115.5 acre-inches per season. This amounts to 3.14 million gallons per acre or 15.75 billion gallons per year on 5000 acres. The maximum design application rate of the Muskegon System is 3.8-4.0 inches per week including rainfall. The average application rate is 2.5 inches per week. The above assumptions and calculations show that additional nitrogen must be supplemented as fertilizer to maintain adequate corn growth. A successful crop growth results in maximum nutrient uptake by the crop and, therefore, a cleaner effluent. The following are the actual on site Muskegon observations on the nitrogen assimilation under field conditions:

Site Data Nitrogen Assimilation

Circle or Field 3	Circle or Field 11
1. 4.91 ppm N leached	3.48 ppm N leached
2. .57 #/A/day leached	.15 #/A/day leached
3. 62.7 #/A leached for season	16.5 #/A leached for season
4. 102.0 #/A total N applied	154.3 #/A total N applied
5. 39.3 #/A N assimilated by diff.	137.8 #/A N assimilated
6. 65 bu/A yield	92 bu/A yield
7. 2.11 Mg/acre	2.15 Mg/acre

Facts:

1. Effluent applied and hydraulic loadings nearly equal.
2. Total P & K applied nearly equal.
3. Maturity of corn nearly equal.
4. Plant stands nearly equal.

Facts (Contd.):

5. Soil types the same.
6. Growing degree units nearly equal.

Assumptions:

1. 1.5 MGD leachate from each drain tile.
2. Equal leaching of N from all fields of a particular tile.
3. Nitrogen fixation cancels denitrification.
4. Soil nitrogen is not depleted or enhanced but remains the same before and after irrigation.

The data obtained from this preliminary experiment substantiates the values taken from Aldrich. Contrary to normal reasoning, supplemental fertilizer applied to field 11 did not cause an increase in the amount of nitrogen lost to the drainage system, but rather a decrease compared to field 3 not to mention a 40% increase in yield.

The following is typical nutrient assimilation in 100 bushels/acre of corn taken from the same source[8].

Total Plant Assimilation in #/acre

N	P	K	Ca	Mg	S	Cu	Mn	Zn
157	27	102	29	25	17	0.07	1.06	0.30

IV. AGRICULTURAL ASPECTS

There are approximately 6000 acres of land area actually under irrigation. Of this about 3500 acres was located in forested land or heavy brush cover which necessitated clearing. The clearing was done at highway specifications.

The farm manager was obtained on May 3, 1972. Activities during this year were limited generally to those of planning. Yield trials of over 40 varieties of corn with different maturities were established and evaluated.

A. Crop Selection

Corn was chosen as the primary crop to be grown at the Muskegon County Wastewater System in the initial years. Many factors were considered in choosing a crop which was applicable to the goals of the system and the conditions of the site. Some of the advantages of corn are listed below:

1. Being a tall foliar crop with good leaf area index, corn transpires tremendous amounts of water.
2. Removes nutrients from the soil complex; especially those being supplied in the wastewater.
3. Very low machinery costs per acre, relatively speaking.
4. Will be easier to establish on the recently cleared rough ground surface, than would be small grains or a forage crop.
5. Low labor requirements; relative.
6. Will be able to utilize the cool, short growing season because of plentiful variety adaptations.
7. The grain produced is a readily marketable product that can be put through livestock, if such a system is deemed feasible.
8. The grain product is an excellent starch and, therefore, energy source for livestock consumption.
9. Being a widely adapted crop, its disease resistance from both soil and air borne insects is good.
10. Corn can tolerate the low pH soils present, better than forages.
11. Corn can withstand early planting on the loose sandy soils, and become better established than forages during the growing season.
12. A cover crop can be easily inter-seeded to prevent wind erosion.

13. If harvesting is delayed for any reason, the nutrient composition of the seed does not change.
14. The crop residue that is not harvested will add tremendous amounts of organic matter, which is later converted to humus.
15. Storage facilities are not nearly as expensive as would be specialized crop storage (equipment storage or other crop storage).
16. Corn is an efficient user of available nitrogen which will decrease the possibility of nitrate leaching.

In summary, corn has been selected as the crop for the first two irrigation seasons because corn can be planted and harvested on relatively rough fields which are wood strewn. The field conditions have eliminated alfalfa or soy beans for the time being. The field conditions also eliminated physically the cropping of wheat; however, inasmuch as wheat is humanly consumed, wheat is out of the question. The economic return on corn is better than oats at the present time, and oats unharvested have the same physical limitations as wheat if not more because of lodging. A poor regional market and late seasonal irrigation schedules which induce grain head fungal diseases limits the use of sorghums. The limitations that the products be animal feedstuffs, industrial or fiber has eliminated all high value crops adapted to this area.

B. Equipment Selection

There was a compromise made in the selection of equipment for the farming operations. With 6,000 tillable acres, the most economical size of equipment would seem to be the very largest; that is, tractors rated at 25 + drawbar horsepower and their complement of tillage equipment[12]. However, because of the field condition, smaller 4-wheel drive tractors were selected. This allowed for a more efficient use of narrower

tillage equipment which is more flexible and maneuverable in poor, sandy field conditions. The heavy offset disc has been the main piece of tillage equipment. In the future, the disc will be replaced more and more by the chisel plow.

The field operations run around the clock, 24 hours per day, to maximize equipment use. Equipment to harvest approximately 50% to 75% of the acreage is owned by the farm. The additional harvesting is accomplished by custom operators. If the farm were to operate all harvesting operations, it would push the manpower demand out of balance. A basic grain handling center with drying facilities and some storage is a necessity for a large farm to allow fast and organized shipment of product. The Muskegon System has a drying capacity of 1000 lbs/hour with the ability to load a 2000 lb semi-trailer in five minutes.

C. Management of Farming Operations

Since the farm operation is an integral part of the living filter concept of land treatment, and therefore, cannot be divorced from the treatment itself, good farm management is essential. The management of this type of farm is unique, however, Management of a farm operation under heavy water applications requires special talents. As stated earlier, supplemental fertilizer must be added to the wastewater to balance the nutrients, optimize crop growth and yield and thereby obtain a cleaner effluent and preserve the soil as a chemical filter. Maximum yields not only mean a cleaner effluent but, also, any profits from the farm operation can be used to offset the cost of treatment.

V. PRETREATMENT

The influent waste stream has not been pretreated when it is received at the site. Before the water can be stored or irrigated a significant amount of the biological oxygen demand (BOD) must be satisfied. This biological treatment takes place in the three (3) aeration cells. These cells are essentially extended aeration cells. The biological treatment (secondary treatment) takes place prior to settling solids. Primary treatment occurs in the two large storage lagoons. Each cell is capable of treating one day's design flow of 42 MGD, and they may be operated in either the series or parallel mode. At the current flow of approximately 28 MGD the cells have a retention time of 1.5 days.

The average influent BOD_5 is about 220 mg/l. At 28 MGD this amounts to 51,000 pounds per day of BOD. At design flow and loading the cells can pretreat approximately 88,000 pounds per day of BOD. At the present time, the BOD is being reduced to 65-75 mg/l during biological treatment. In order to conserve energy only two cells are operating in the series mode with only the equivalent of 1 cell's aeration. Sufficient oxygen is being supplied to maintain a low dissolved oxygen and the two cells allow enough retention time to reduce the BOD load to an acceptable level.

The load limitation of the effluent from biological treatment cells is based on the design of the storage lagoons. The storage lagoons are designed to assimilate a loading of 20 pounds per acre per day or 17,000 pounds per day of BOD each.

VI. MONITORING LAND TREATMENT OF WASTEWATER

Generally, conventional wastewater treatment plant operations include collection of wastewater, physical and biological treatment, disinfection and discharge into the receiving surface water. The conventional system operates continuously, every day of the year and discharges continuously. In these operations monitoring of the wastewater is done before, during, and after the treatment to assure the quality of the discharged water meets the regulatory agencies discharge standards.

Land treatment of wastewater designs are (or should be) environmentally enclosed systems. Like the conventional system the liquid waste is collected, transmitted, treated or pretreated, disinfected and discharged. But the most important difference in comparing the land treatment and the conventional system is that after the biological treatment (pretreatment) and before the discharge into the surface water, storage and living filter processes are taking place; thus, the pretreatment is done continuously, but the discharge is done seasonally.

The process of renovating water by land treatment systems requires much more involvement and considerations than conventional treatment, the difference is management. The involvement required is extensive monitoring programs of all facets of land treatment. Data obtained from these programs are the key to the management decisions. Monitoring the complex renovation process is essential for establishing safeguards against possible pollution of soil, groundwater and surface waters and air. Environmentally sound designed systems, poorly managed, could do a great injustice to the system. Therefore, management considerations are as important as the design criteria. The monitoring of the Muskegon system is designed to take into account the influent, biological treatment (pretreatment), storage, post chlorination, post irrigation (drained), lagoon seepage, groundwater, surface water, residential wells, soil and crop characteristics. The monitoring program should take into consideration the measurement of parameters that are important from the public health aspect, federal, state and local government ordinances and recommendations. The program also includes the agronomical practice and energy conservation considerations[11].

IMPORTANT MONITORING SEGMENTS OF LAND TREATMENT PROCESS

1. Influent or Sludge Quality (Treatment Quality)
2. Soil Condition and Quality (Preservation of Soil's Physical & Chemical Characteristics)
3. Drained or Leachate Water Quality (Prevention of Contamination of Surface and Groundwater)
4. Crop Quality and Yield (Safe for Animal/Human(?) Consumption)
5. Economics/Energy Savings and Fertilizer

1. Influent and/or Sludge Quality

Influent

a. Nutrient levels(N,P,K,)
b. Sodium absorption ration(SAR)
c. Heavy metal concentration, having potential toxicity to plant & animal life(Zn,Cu,Ni,Cd,Pb,Hg)
d. Other physical and chemical determinations (pH,BOD,COD,T.S.,TOC)
e. Pathogens, viruses, salmonella and protozoa

Sludge

a. Nutrients levels (N,P,K & in what form)
b. Heavy metal concentrations having potential phytotoxicity and animal toxicity effect
c. Organic material (qualification/ quantification)
d. Pathogens, viruses, salmonella

2. Soil Condition and Quality

a. Nutrient profile - N,P,K distribution
b. Cation exchange capacity
c. Hazardous heavy metal distribution
d. Organic content
e. Soil kind - physical
   -infiltration rate
   -size distribution
   -soil horizons
   -redox profile, pH

3. Drained or Leachate Water Quality & Groundwaters

   a. Nutrients (NO_3/NO_2,P)
   b. Heavy metals
   c. Pesticides, herbicides, etc.
   d. Microbiological
      -fecal coliform
      -fecal strep
      -salmonella
      -viruses
   e. Other physical, chemical determinations
      -pH, specific conductivity, detergents

   Receiving Surface Waters

   a. Nutrients
   b. Heavy metals
   c. Microbiological
      -fecal coliform
   d. Other physical and chemical determinations

4. Crop Quality

   a. Heavy metals content
   b. Nutrient content
   c. Pathogens
   d. Yield Bu/Acre

5. Economics

   a. Treatment cost saving
   b. Fertilizer cost saving
   c. Fertilizer production energy saving
   d. Crop yield - sales (offset operations cost)

VII. RESEARCH PROGRAM

The Muskegon County Wastewater Management System is a demonstration project. There is an active research and development program associated with it. The EPA research grant is 11010GFS. There is about $1.935 million for research and development; 75% federally funded and 25% county. The following is the list and a brief description for each research and development activity that the county of Muskegon is active in.

A. Surface and Groundwater Quality Monitoring

The purpose of the surface and groundwater monitoring program is to establish background data or base line information on physical and chemical characteristics before the wastewater system goes into operation, and monitoring after the wastewater treatment goes into operation. There are six (6) surface water bodies monitored. All the surface waters flow into Lake Michigan. Figure 6 shows the surface water bodies. The following are the surface waters.

1. Mosquito Creek
2. Muskegon River
3. Muskegon Lake
4. Big Black Creek
5. Mona Lake
6. Lake Michigan

There are essentially three (3) different types of wells. They are the Lagoon Seepage, Perimeter or Observation and Treatment Performance Wells. There are a total of 210 of the lagoon seepage wells, forty six observation wells located on or near the site boundary, and 16 treatment performance wells located at the northern part of the site. Figure 5 shows the sampling locations and drainage system of the surface water and Figure 7 shows the groundwater well locations. The time duration of this segment of study is five years.

B. Treatment Performance Studies

The purpose for doing this study is to demonstrate the most effective and efficient way of treating the wastewater. Also included is how the irrigated wastewater is being treated on the soil (living filter concept).

FIGURE 6

SURFACE WATER DRAINAGE FROM IRRIGATION SITE

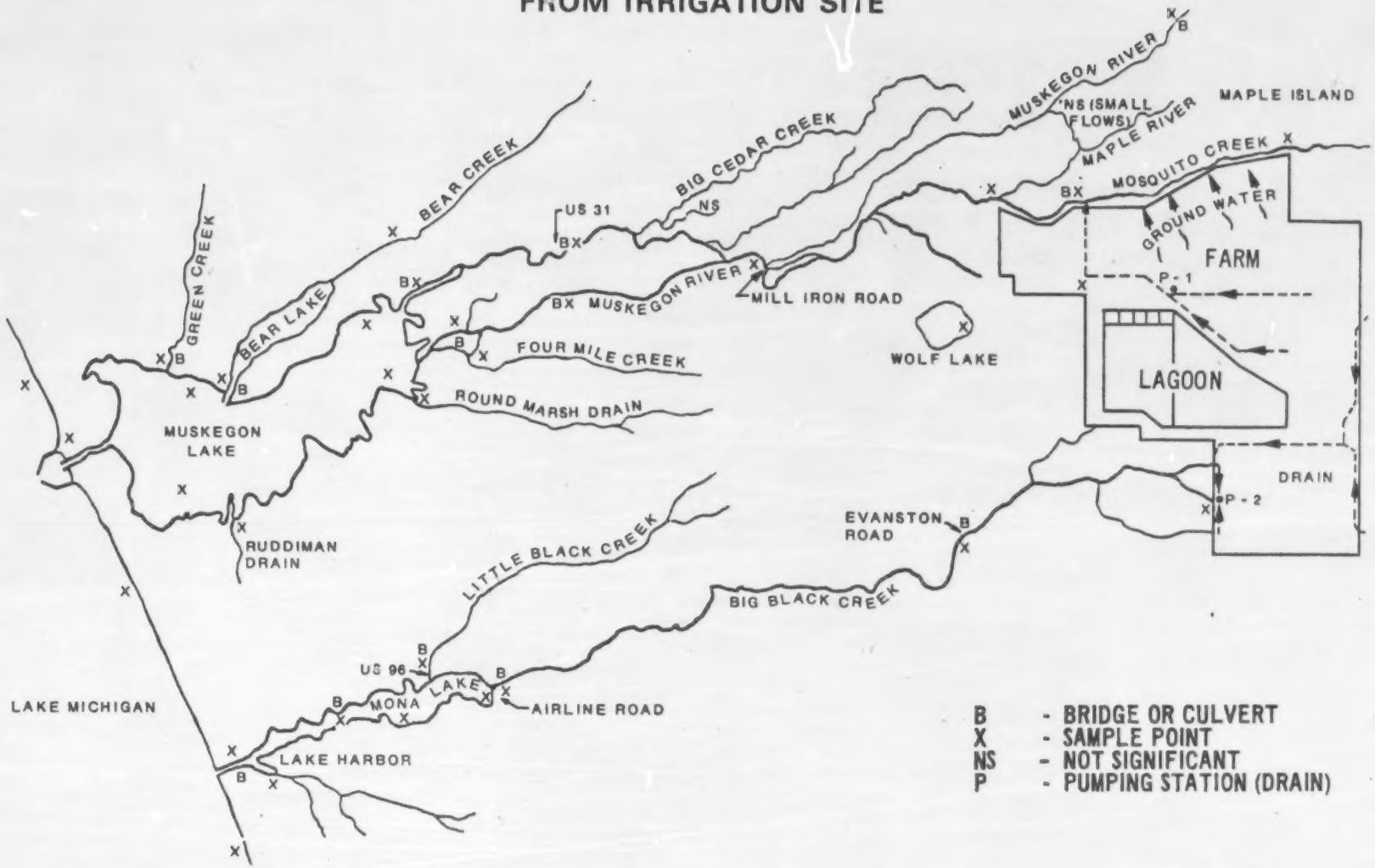
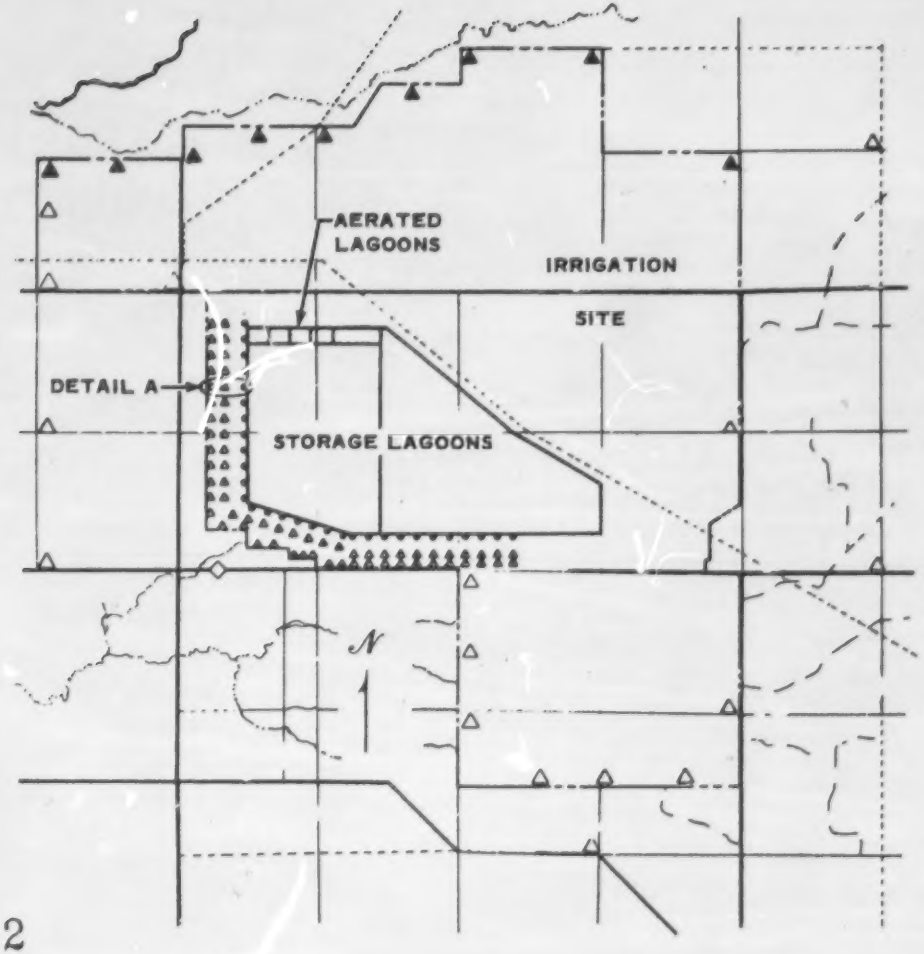
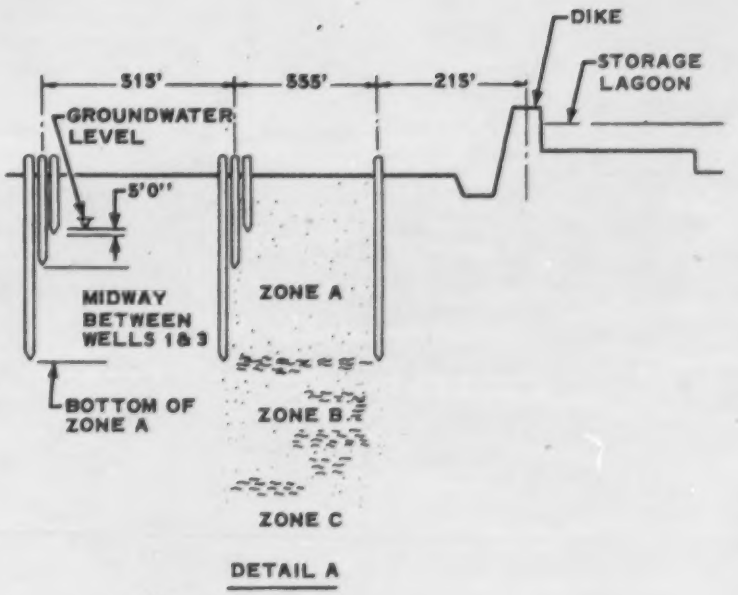


FIGURE 7

GROUNDWATER OBSERVATION POINTS





LEGEND

- △ THREE WELL CLUSTER AROUND SITE AREA
- ▲ THREE WELL CLUSTER AROUND STORAGE LAGOON
- ⊙ SINGLE WELL AROUND STORAGE LAGOON
- ---- TREATMENT PERFORMANCE STUDIES
- △ SITE BOUNDARY

Table 6 lists the sampling locations for treatment performance, and Figure 8 shows the sampling locations. The duration of this work component is three years.

C. Agricultural Productivity Studies

The purpose for doing these studies is to demonstrate what crops are best suited to grow on the Muskegon Project; whether there will be toxic constituents in the wastewater to affect the plant growth, and whether there will be any characteristic changes in the soil that could be detrimental to crops. This study will continue for four years.

D. Socio-Economic Studies

The purpose of this work component is to determine the impact of the Muskegon County Wastewater System on the local economy; whether the system will draw new types of industry into an area that is at the present time mainly dependent on the automotive industry. This program is being undertaken by Bauer Engineering, Inc. of Chicago.

E. Wells

This segment of the R&D program was devoted to construction of the drainage and observation wells.

F. Management of Project Farm Operations

The farm management program is designed to have a competent farm manager and to develop the detailed plans for initial agricultural activities. Also, a Master Farm Plan was developed for effective use of all the farm acres.

Table 6 - Sampling Locations

A. Pump Stations (downtown)
   (1) Station "D"
   (2) Main Station "C"

B. Influent
   (1) Inlet to Treatment Cells

C. Biological Treatment
   (1) #1 Aerated Lagoon
   (2) #2 Aerated Lagoon
   (3) #3 Aerated Lagoon

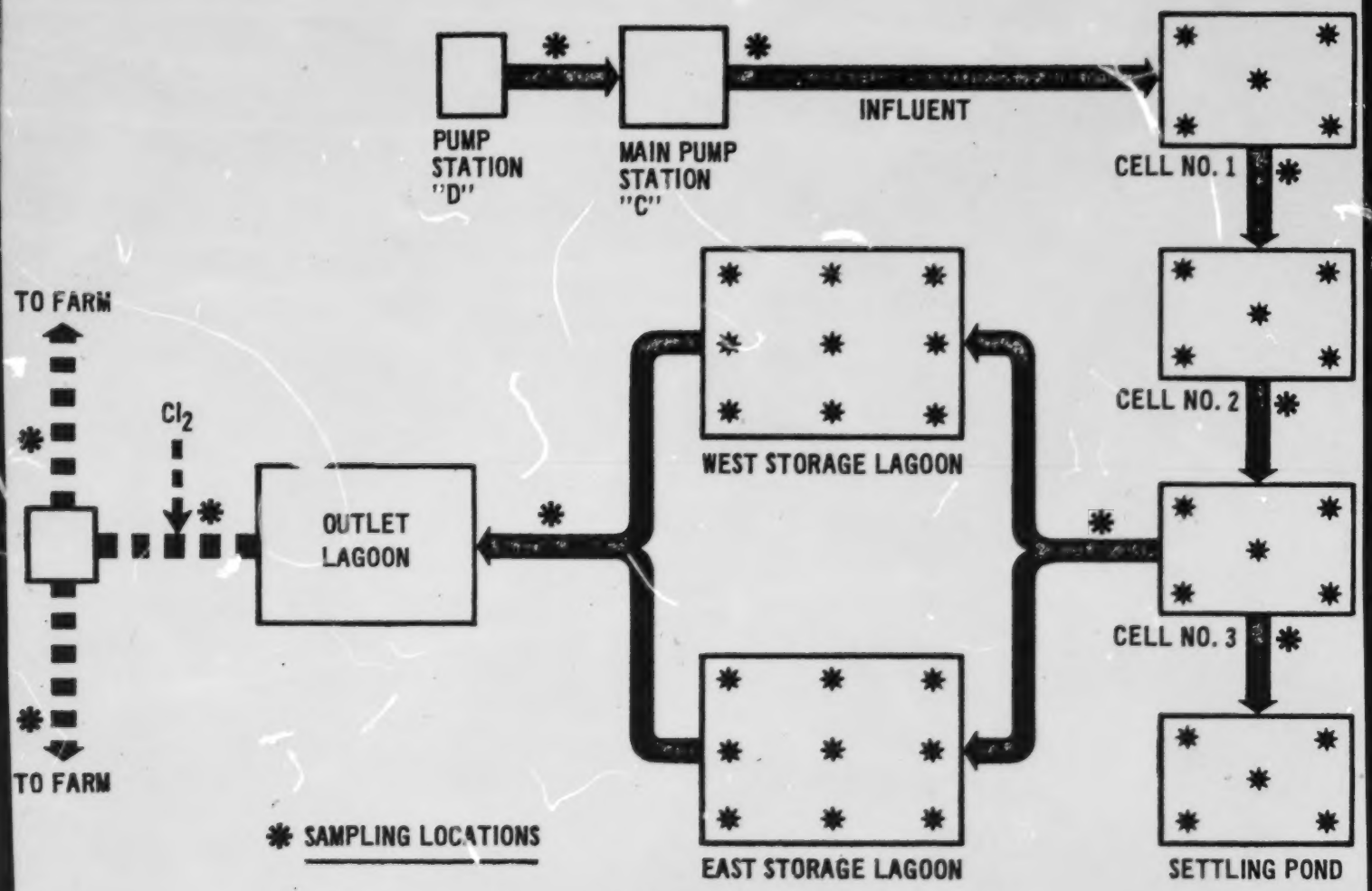
D. Post Treatment
   (1) #1 Storage Lagoon
   (2) #2 Storage Lagoon
   (3) Settling Lagoon*
   (4) Outlet Lagoon*
   (5) Sprayed Water**
   (6) North Observation Wells
   (7) Drain Pump P-3 (South)
   (8) Drain Pump P-4 (North)
   (9) Outlet to Mosquito Creek
   (10) Outlet to Big Black Creek
   (11) Drain Pipe Samples (irrigated water, filtrate)

* Whenever in use

** Or chlorinated water during farming operations

FIGURE 8

FLOW DIAGRAM OF SAMPLING LOCATIONS



The purpose of continuing the Farm Management Grant is to insure continued success of the farm operations, as well as supplying information on agricultural operations in conjunction with wastewater spray irrigation.

It is important that the farm manager understands: (1) deployment of labor and equipment on a large farm; (2) planting and harvesting schedules; (3) herbicide and pesticide spray schedules; (4) hiring of temporary labor in peak work periods; (5) equipment, its use and its maintenance; and (6) the nature and potential of the farm soil.

VIII. CURRENT STATUS

A. Introduction

Land acquisition, relocation, dislocation, and moving began in 1970 and was completed within a year. This phase of the project was done efficiently and remarkably fast. Construction of the wastewater facility began in 1971. Land clearing, construction of the treatment cells and lagoons, installation of the transmission force main and new lift stations were the priorities. After these items were completed and the necessary tie-ins were made, the wastewater was pumped to the site. This began in May of 1973. This may have been premature because the irrigation machine contract had not been let at that time but the County needed the revenues from the gallonage fee, and the State of Michigan Department of Natural Resources concurred with the County for the early start. It was also anticipated that some of the irrigation machines would be ready late in the irrigation season and enough water could be irrigated to prevent high water conditions the next spring. Unfortunately, this was not the case and no irrigation took place in 1973.

By spring of 1974, over one year's wastewater was biologically treated and stored in the storage lagoons; the high water levels were exceeded in both storage lagoons. Irrigation began in late May of 1974. At that time only 20 of the 54 irrigation rigs were available. Wastewater was irrigated wherever rigs were available. Maximum amounts of water were applied, over 4"/week; this was accomplished by opening the end caps of the irrigation rigs. This heavy application rate was done to lower the high water levels from the storage lagoons, it lasted only for one month. A wet spring and maximum applied water caused corn crop damages. Maximum application rates continued through late November, 1974. At that time, the east storage lagoon level was at the low water level and the west storage lagoon had been lowered to 4.7 feet above low water level. The water quality of the west storage lagoon met State and Federal standards for direct discharge due to waste stabilization action during the long storage period and dilution from the lagoon seepage water pumped back into this lagoon. This remaining water was slowly discharged from December 1974 through February 1975. Under these adverse conditions in 1974, there was adequate crop yield, approximately 50 b/acre. After dehydrating and deducting for foreign matter the yield was 37 b/acre as

No. 2 yellow corn (37 b/acre net salable).

B. Results of the First Irrigation Season

1. Treatment Performance

The 1973-1974 treatment performance study results show that the Muskegon County Wastewater System is treating the wastewater influent very effectively. The treatment cell/cells are reducing the biological loading by a factor of 50% in Cell 1; reduction is from 220 to 105 ppm. The second biological cell is reducing the load by a total of 70% from 220 to 65 ppm. There is a loss of ammonium nitrogen going from Cell 1 to Cell 2 from an average of 9.0 ppm in the influent to 4 ppm leaving Cell 2. There is a slight loss in phosphorus during biological treatment. There are no substantial changes in the other chemical and physical parameters in the influent going through the treatment cells. In the storage lagoons, the treated wastewater quality is changing substantially. In the west storage lagoon where the wastewater has been in storage and impounded for almost over a year, the water quality has changed the most dramatically. Biological loading has been reduced to 5 ppm. Oxygen levels are at saturation. The pH level is stabilized. All the cations and anions have been reduced by 70 - 50%. This is due to either dilution by the interception ditch water or by complextion; i.e., phosphate with metals. Nitrogen levels have been reduced by denitrification or by plankton and phytoplankton uptake. Bacteriological data show reductions or organisms to below 200 organisms/100 ml for fecal coliform organisms. The water quality had not changed as dramatically in the east storage lagoon where the wastewater was not stored as long as the west lagoon. The biological loading has been reduced to 20 ppm. The pH level is stabilized. There are no changes in the specific conductivity readings and incoming nutrient levels. In the nutrient species, the ammonia is being converted to nitrate/nitrite, but the total concentration level of N is staying the same - about 5 ppm or more. The other parameters do not indicate major reductions.

The drain tile water quality analysis indicates a certain degree of change. The trend of the physical parameters indicates a reduction in concentration of the specific conductivity, pH, color, turbidity, etc. The bacteriological results show a mixed pattern and no trends are indicated. There is a reduction in Na^+ and Cl^- concentrations by a

factor of 50%. Sulfate and iron concentrations are either the same or increased; this is due to the high iron and sulfate content in the farm site soil, equilibria has not taken place yet. The nutrient picture shows there is a substantial reduction in phosphate levels from 5 ppm to 0.07 or less, almost 99% removal. The nitrogen picture is very difficult to evaluate at this time because the leachate in instances contained more than the irrigated water. This could be attributed to the nitrogen levels in the soil from prior years (history), and most important of all the heavy application rate of irrigation all throughout the season could cause excessive amounts of nitrogen leaching out. There is a trend of reduction in the nitrogen levels in the drain tile water; this is observed from the drain tile water data collected recently. The nitrogen problem will be looked into in 1975 irrigation season. Nevertheless, there is about a 50% reduction in the nitrogen concentration levels from the irrigated water by the soil and crop uptake. The discharge water quality into the streams shows the same general trend as in the drain tiles, but the concentration is somewhat lower in most parameters. This is due to groundwater mixing and diluting the drain tile water. Table 7 summarizes the treatment performance results.

The treatment performance studies indicate that the system is capable of treating higher loads of liquid waste. At the present time, equivalent of one cell is in operation. From 1974 operations and from the first quarter of 1975 operations it is estimated that the three treatment cells could effectively reduce the biological demand load in the event that the flow doubles from the present 28 MGD. In the storage lagoons observed water quality indicates that the designed system could handle higher flow volumes and loading from the design capacity. The 1974 irrigation experience shows that the higher hydraulic and biological loading can be tolerated in the farm fields.

2. Water Quality Monitoring

Sampling sites were selected to implement the monitoring of surface and ground water quality throughout the watershed area of the Muskegon County Wastewater System, including Lake Michigan. The objective of the surface and ground water monitoring is to supply base line data before the system goes into operation, and to follow up the tracing of any changes which might occur between each sampling location during the

TABLE 7

SUMMARY OF TREATMENT PERFORMANCE

Parameter	Influent	Discharge From Cell 1	Discharge From Cell 2	Storage Lagoon East	Storage Lagoon West	Drain Tiles	Mosquito Creek	Black Creek
BOD ppm	220	105	65	20	5	2.2	2	2
DO ppm	0	1	2	3	8.5	2-9	9.5	1.6
Temp. ^{o}C	24	24	20	1-26	1-26	-	1-5	12
pH	7.5	7.5	7.6	7.6	8.2	7	7.2	6.8
Sp COND µmhos	1300	1100	1100	1200	750	600	750	800
TS ppm	1050	950	1000	750	550	-	375	700
TVS ppm	500	400	380	300	200	-	160	150
SS ppm	325	250	250	20	10	-	10	30
COD ppm	550	350	325	140	70	-	30	25
TOC ppm	140	75	70	30	20	5	10	10
NH_4^+ ppm	9.0	6	4	2.5	0.2	0.40	0.45	0.5
NO_3/NO_2 ppm	0.0	0.07	0.1	2.5	0.8	2.8	1.9	1.4
PO_4^{3-} ppm	6.5	5	5	5	0.7	0.05	0.1	0.05
SO_4^{2-} ppm	85	100	100	95	70	150	80	320
Cl^- ppm	175	170	170	160	90	50	60	18
Na^+ ppm	150	150	150	145	85	40	40	7

TABLE 7 (cont'd)

SUMMARY OF TREATMENT PERFORMANCE

Parameter	Influent	Discharge From Cell 1	Discharge From Cell 2	Storage Lagoon East	Storage Lagoon West	Drain Tiles	Mosquito Creek	Black Creek
Ca	70	70	70	65	60	70	60	110
Mg	16	16	16	16	16	25	20	40
K	11	11	11	11	6	2.8	5	2.5
Fe	1.25	0.75	0.75	1.0	0.7	4.0	0.08	0.4
Zn	0.9	0.5	0.5	0.25	0.15	0.06	0.1	0.2
Mn	0.25	0.25	0.25	0.25	0.08	0.15	0.08	0.4
Color Units					100	20-150	130	
Turbidity Jackson Units					2.8	0.1-50	4.5	
Total Coli (units/100 ml)					0-1.3×10^5	10-1000	40-1.5×10^4	
Fecal Coli (units/100 ml)					0-2400	0- 440	1-1500	
Fecal Strep (units/100 ml)					0-2300	2- 700	7-5500	

course of operation. Figure 5 shows the surface waters and sampling sites. The frequency of sampling of surface waters were done on a monthly basis whenever feasible until June of 1974, and then quarterly. The quarterly sampling will continue through 1975. Beginning with January of 1976, monthly sampling will begin again and will continue for the remainder of the grant period. Sampling of the groundwater wells began when the wells became available. Basically, the lagoon seepage wells were sampled semi-annually and the perimeter wells were sampled monthly. Since the original start-up, the lagoon seepage monitoring program has been stepped up to sample these wells three (3) times per year rather than semi-annual samples.

Water Quality Monitoring - Results

The preliminary results obtained in the Surface and Groundwater Monitoring programs have indicated that certain changes are taking place. At this time, however, it may be premature to say that these are trends. Since the system has only been in complete operation for one irrigation season, the changes indicated are only observations of the first year's operation.

a. Surface Water Monitoring

The greatest immediate impact of the Muskegon County Wastewater System has been on the receiving streams. Increases in turbidity, conductivity, chlorides, sulfates, iron and the alkali-earth metals have been noticed. Downstream stations show less change or impact which is to be expected considering dilution. In the two lakes monitored, little effect was noticed. In Muskegon Lake, the results show essentially no change and no trends are apparent. The results in Mona Lake are similar but certain trends may be developing. During the last year of monitoring, phosphate levels have decreased. Iron, on the other hand, has increased.

b. Groundwater Monitoring

In the lagoon seepage wells, increases in conductivity, low level chloride, and nitrate/nitrite nitrogen have been observed. During the same time period, changes in the direction of groundwater flow and fluctuations in the groundwater table make these observations hard to interpret. Similarly, the perimeter wells have shown some fluctuations; however, no obvious trends have developed.

3. Socio-Economic Studies

The following short-term impacts, based on early data collection have been identified as follows:

a. Formulation of community development programs. INDEX is utilizing the WMS as a key incentive in attracting industry to the Muskegon area. MADC-CC is proceeding with its downtown Muskegon development program in conjunction with the rehabilitation of the Muskegon Lake shoreline. Various organizations are promoting tourism and recreation in Muskegon Lake through advertising and efforts to improve sport fishing.

b. Implementation of Muskegon lakefront developments. The Lakey Foundry site has been purchased by the City of Muskegon and plans for it compatible with a aesthetically pleasing lakefront are being prepared. The Giddings Street boat launching ramp has been expanded. Plans for other lakefront developments are under discussion.

c. Utilization of the WMS site for other purposes. A solid waste management site has been developed and put in operation. The Consumers' Power Company has taken an option on land within the WMS site for a nuclear power generating plant. Numerous other plans for industrial location at the site and recreational use of the site are under discussion.

d. Affects on community decision-making. County government has taken a much larger role in community decision-making, utilizing its sponsorship of the WMS as a stepping stone to other community involvements. The number of formal and informal organizations coordinating their activities with County-wide programs has increased. Also, there are indications of a prevalent positive mood in the community regarding future development, particularly with respect to Muskegon Lake.

e. Expansion of wastewater treatment services in Muskegon County. Virtually all potential point discharge polluters have been or are being incorporated into the WMS.

f. Expansion of existing industrial activity. The WMS has been an acknowledged factor in expansion of two Muskegon industries: S. D. Warren paper mill and the Ott Chemical Company.

4. Agricultural Productivity

A soil monitoring program was initiated on the Muskegon System in the fall of 1973 prior to any effluent irrigation. At that time soil samples were taken from numerous sample points located throughout the farm. These were taken in increments to a depth of 60 inches as follows: 0 to 6", 6" to 12", 12" to 24", 24" to 36", 36" to 48" and 48" to 60" Data obtained from analysis of these samples serves as a baseline for the soil monitoring program. In the fall of 1974 after one year of irrigation, samples were again taken. Starting in the spring of 1975 samples will be taken prior to and after irrigation each year for the remainder of the research grant. Parameters being monitored are pH, buffer pH, organic matter, exchangeable Na, exchangeable Ca, exchangeable Mg, exchangeable K, extractable Zn, cation exchange capacity, total Kjeldahl N, available "NO_3" N, available "NH_4" N, total P and available P.

In the sample point areas, irrigation the first year ranged from 1.4 to 128.7 inches. This resulted in a wide range of effects on the soils. Generally, pH increased in soils. Of the 72 sample point increments 38 showed an increase, 29 showed a decrease and 5 showed no change. Increases were primarily associated with effluent applications above 30 inches while decreases tended to be from areas which received less than 30 inches of effluent irrigation. As would be expected the most marked changes in pH occurred at the 0 to 12" increment. The average increase was 1.0 while the average decrease was 0.7. From 12" to 36" depth, the limit of the fall 1974 sampling, changes were less marked but quite observable. The average increase was 0.5, the average decrease 0.7. At this time the only other comparison data available is for the alkaline earth metals sodium, calcium, magnesium, and potassium and this data is not yet complete. Available data does, however, indicate a dramatic increase in exchangeable sodium. Calcium, magnesium and potassium generally increased but many sample point increments showed decreases. It is yet too soon to draw any definite conclusions concerning these three metals.

Corn test plots were put in during the 1974 season to evaluate different effluent application rates and the use of a supplemental fertilizer.

Six different test situations were set up in duplicate:
1.0" effluent application/week, no fertilizer
1.0" effluent application/week, with supplemental fertilizer
2.5" effluent application/week, no fertilizer
2.5" effluent application/week, with supplemental fertilizer
4.0" effluent application/week, no fertilizer
4.0" effluent application/week, with supplemental fertilizer
Soil test data for the area indicated sufficient available phosphorus in the soil but a deficiency of available potassium. Supplemental fertilizer, therefore, consisted of 150 #/A K_2O. No additional nitrogen was applied. Effluent irrigation began on June 5 and terminated on October 5. This time period less ten days breakdown time for the rig gave 112 days of effluent irrigation to the test plots. Total effluent application to the plots was 16 inches for the 1" per week plots, 40 inches for the 2.5" per week plots and 64 inches for the 4" per week plots. Table 8 shows the amount of nutrients applied via the effluent in #/A.

TABLE 8

NUTRIENTS APPLIED IN EFFLUENT

Treatment	Total	#/A N	#/A P	#/A K
1.0"/week	16"	14.5	5.3	34.7
2.5"/week	40"	36.1	13.3	86.7
4.0"/week	64"	57.8	21.3	138.8

Results from like test plots were averaged and are presented in Table 9

TABLE 9

Plot	Wet Earcorn Wt.	% Moisture	Calculated Yield
1.0" Eff. No Fert.	6200 #/A	27.1	74.2 bu/A
1.0" Eff. w/Fert.	3650 #/A	26.5	44.0 bu/A
2.5" Eff. No Fert.	5550 #/A	28.1	65.2 bu/A
2.5" Eff. w/Fert.	7425 #/A	27.7	88.5 bu/A
4.0" Eff. No Fert.	7250 #/A	29.6	83.9 bu/A
4.0" Eff. w/Fert.	7525 #/A	26.7	90.9 bu/A

Addition of supplemental fertilizer seemed to have resulted favorably at the 2.5 inch and 4.0 inch effluent application rates; however, at the 1.0 inch application rate fertilizer appeared to have been detrimental. Generally the higher application rate of effluent resulted in higher yield. This was most likely due to the increase in nutrients which the effluent supplied (see table 9).

5. Engineering and Operations

As can be expected, for a system of this size and complexity, certain operational problems have been identified during the initial irrigation season. These are the following:

a. Dike damage.
b. Failures in the pressure pipe distribution system to the irrigation machines.
c. Failures in the underground electrical cables to the irrigation rigs.
d. Odor

Investigation and/or corrective action has been undertaken in all of the problem areas. A brief discussion of each of these follows:

Dike Damage

In the early spring of 1974, during ice cover break-up in east storage lagoon, some damage was incurred to the soil cement lining of some sections of the northeast wall during high windstorms. This could be attributed to several factors. One factor could be the extreme high water levels in the lagoons at that time. Another factor could be that this particular section of the dike wall was one of the first sections to be constructed and construction difficulties in either mixing, quantities or application of the soil cement material. Investigation into the problem is continuing and further observations are required. The dike lining could have been constructed with stronger mixtures and material, but the cost would have been unbearable.

Total damaged area was probably less than 10% of the dike area. After the level of the east lagoon was lowered the damage was repaired. The 1975 winter does not show any major dike damages; there are a few patches which will be repaired during the irrigation season as the water level subsides. There will be normal dike maintenance repairs each year; it is expected from an 11 to 12 mile long dike.

Pressure Pipe Distribution System

During the irrigation season, there was a high frequency of sleeve and pressure pipe breaks in the underground distribution system to the irrigation machines. There is no consistency in the pipeline breaks. Valves were installed to prevent high surge pressures during start up and shut down; this did seem to help some but did not correct the problem completely. Among many possibilities the pipe could have been damaged in either transportation or installation, specifications, and manufacturing are also being checked. Investigation into this problem is continuing. Most repairs have been undertaken as the leaks are discovered. At the present time there are no broken pipes; there may be one pipe leak, but it will be repaired in April.

Electrical Cables

At the present time about 16 rigs are inoperable due to electrical cable faults. These faults could be caused by pin holes on the cables; it is under investigation how these pin holes showed up; there could be other causes for these faults such as holes, lightening, arching, etc. This problem is still not well defined and the study of this problem is continuing. Repairs to damaged sections are currently being done, by splicing and replacement.

Odor

Every treatment system has an odor problem to one degree or another. The Muskegon system is no different. County investigation into this problem was undertaken in late 1973. At that time it was discovered that the odor was attributable to reduced organic and inorganic forms of sulfur. Corrective action was taken and the odor was reduced by about 90%. The remaining 10% may be objectionable to some. It is intermittant which could be attributable to the industrial activity. Work is continuing on this problem with the goal being the first odor free treatment system!

1975 Operational Plan

The 1975 operational plan is significantly different to the operations of 1974. During the 1974 irrigation season, for example, treated wastewater was applied to the land at high rates of 4 inches per week or more by opening the end caps. This high rate of application was practiced regardless to rainfall or with little regard to the crop; operations were carried on 24 hours per day, 7 days per week. This was due to the extremely high wastewater levels in both storage lagoons after more than one year of storage without irrigation. Also, after last year's experience, emphasis is being placed on electrical energy conservation throughout the treatment site, reduction in manpower requirements (operations and maintenance, farming operations, and the laboratory), reductions in chlorine usage and reductions in herbicides and fertilizers and other farm chemicals. It is felt that this operations plan will give us the flexibility to optimize the treatment, attain good discharge water quality, conserve electrical or other energy requirements and to take into consideration the crop needs. High water quality is directly related to successful crop yield.

The following plan consists of the minimum requirements to achieve these goals. It is also believed that these minimum requirements will be attained. These "minimum requirements" will be the results under the adverse unexpected conditions (bare minimum).

TREATMENT MODE

For the first two months of the irrigation season (April and May), the irrigation water will be composed of freshly aerated and settled wastewater. Make-up water will come from the West Storage Lagoon. During this period Cell 1 will be secured and Cells 2 and 3 will be operated in series or parallel as the conditions exist. The wastewater

will then be settled and irrigated. Only enough aeration will be provided to obtain necessary biological treatment, thereby minimizing electrical consumption in the aeration cells and minimizing ammonia nitrogen loss. The purpose of this mode of operation and extended irrigation is: (1) to ease the irrigation schedule, (2) to build up fertilizer in the soil for the crop season, and (3) to reduce energy and manpower costs by early irrigation.

During this irrigation period the East Storage Lagoon will be impounded. Based on the information obtained during the 1974 season, it is expected that the water quality in this lagoon will improve as did the West Lagoon during the stabilization period. Further B.O.D. reduction and natural die-off of bacteria could minimize the chlorine consumption. Loss of nutrients during storage would also be a benefit since this water will be irrigated during the higher water demand period and can be utilized at these higher application rates with less chance of water quality degradation in the leachate.

IRRIGATION SCHEDULE

Irrigation will take place approximately five (5) days per week. The flexibility built in this plan is such that if irrigation is down during the week due to heavy rain, irrigation could continue over the weekend. This five day irrigation schedule has several advantages. For example, supplemental nitrogen can be applied at the end of the week, allowing a weekend dry-down period for nitrogen stabilization in the soil and uptake to the plants. Other advantages include the following: (1) this irrigation schedule would not overload the discharge locations, (2) limit hydraulic loading to the soil, and (3) higher water quality at the outfalls can be expected.

6. Farming Operations

The 1974 season was the first year of full farm operation. Approximately 4500 acres were planted to corn. It was also the first season in which effluent was irrigated. Of the total acreage planted about 3000 acres was newly cleared ground. Preparation of a seedbed in this soil required a great deal of effort. As many as five discings in some areas were required. The major piece of tillage equipment used was the heavy duty off-set disc having a tillage depth of 6 to 8 inches. Planting closely followed seedbed preparation. Air planters were used to plant all acreage. Plant populations ranged from 13,500 to 21,600 plants/acre.

Some commercial nitrogen fertilizer was applied by broadcast methods prior to planting and by dissolution in irrigation water intermittantly throughout the growing season. Irrigation began the last week in May and ceased around the 20th of November. A soil insecticide was used in addition to broadleaf and grass herbicides.

Harvest began during the last week of September and continued until the middle of November. Approximately 3400 acres were harvested using the farm's two eight row combines. The remaining 1100 acres were harvested by a custom operator. Harvest yields ranged from 0 to 92 bushels/acre, the average being approximately 50 bushels/acre over the entire farm. Specific problems over large areas of the farm account for this yield. They are as follows:

1. Over 1000 acres was planted too late due to delays caused by project land clearing operations.
2. More than 1600 acres droughted early in the season through mid July due to lack of irrigation water caused by incomplete irrigation rigs.
3. A nitrogen deficiency was observed in 32 of the irrigation rig areas due to delay in completion of the rigs.
4. Phosphorus and potassium deficiency was observed in all areas sometime during the season, due to delay in irrigation rigs completion.
5. Some losses during harvest caused by low ear placement were the result of crop response to drought and a cooler than normal season.

Farm Plan for 1975

At this time it is estimated that there will be approximately 5,000 acres planted to corn in 1975 at the Muskegon County Wastewater System No. 1.

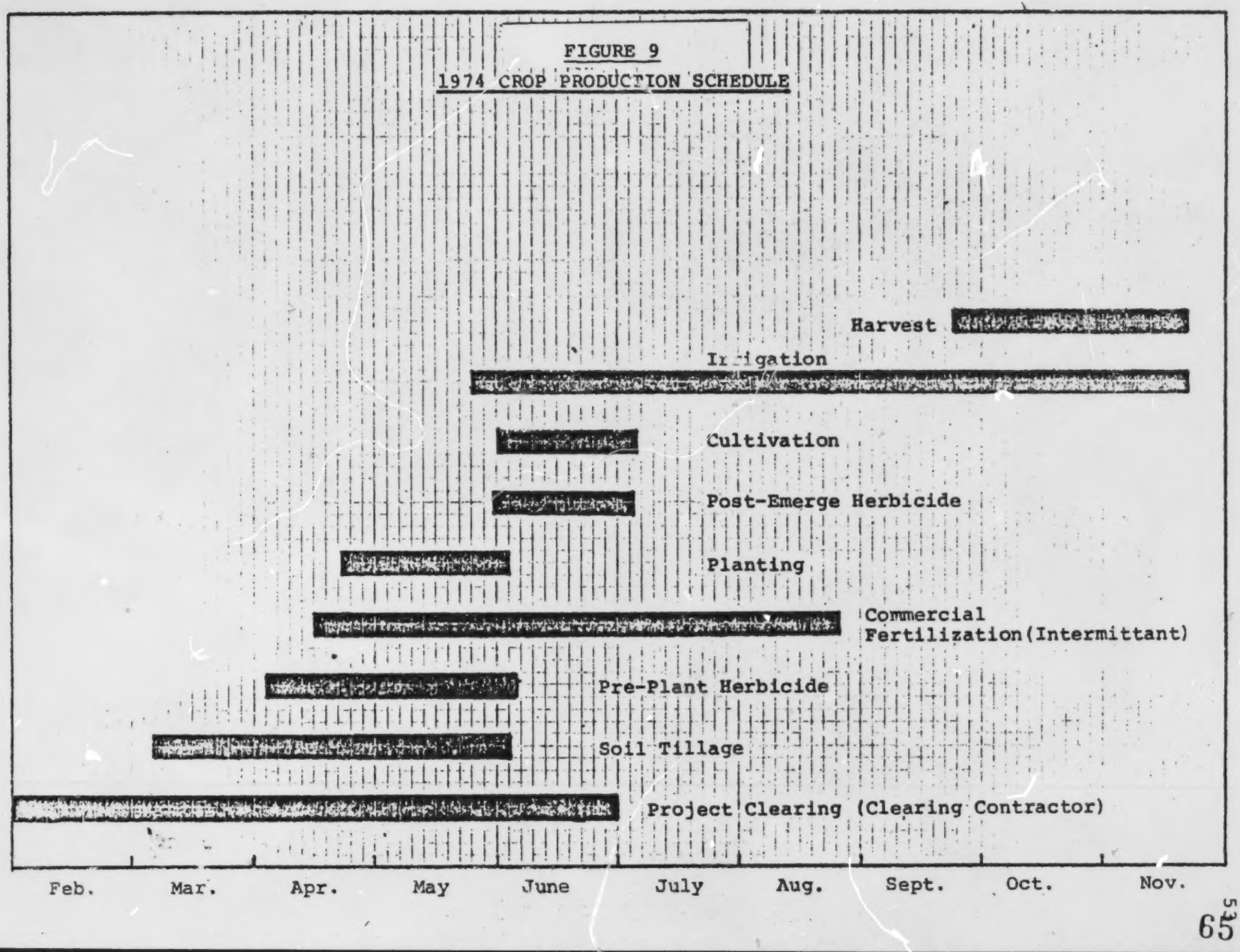


FIGURE 9
1974 CROP PRODUCTION SCHEDULE
Harvest
Irrigation
Cultivation
Post-Emerge Herbicide
Planting
Commercial Fertilization (Intermittant)
Pre-Plant Herbicide
Soil Tillage
Project Clearing (Clearing Contractor)
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.

The results of the 1974 season indicated, however, that either too little or too much wastewater irrigation had a disastrous effect on crop yield and quality. The main tillage operation will begin early in the spring soon after soil thawing occurs. The task will be performed by heavy duty off-set discs. Four off-set disc units will be pulled by four-wheel drive, articulated, 165 drawbar horsepower tractors. The tillage operation will take approximately 300 field-hours.

Corn planting will commence as soon as the soil temperature reaches 49° on a rising temperature pattern. It will be planted with four, eight-row, cyclo air planters equipped with electric monitors. The plant population will vary between 30,000 and 17,000 depending upon the soil type, available nutrients, estimated amount of effluent application, corn variety, etc. Row spacing will be set at 30 inches. The planters will work around the clock once planting has begun. The planting operation will take approximately 200 field-hours and should be completed within 10 to 12 days.

It was determined in 1974 that the insect population was not enough to warrant use of insecticide; therefore, insecticide will not be used at planting time. If, however, an insect problem should arise, this option will be used.

A pre-emergence application of herbicide will be applied to all planted acreage. A combination of Atrazine, Lasso, and Sutan will be used based on the performance in 1974. If injection equipment is received in time, some herbigation may be attempted with the Atrazine-Sutan combination. Where weed problems persist, a post-emergence application of crop oil and Atrazine and/or field cultivation will be used. This was found to be quite successful in 1974 in problem areas. There will be starter fertilizer of a 8-8-8 analysis applied to one fourth of the acreage. This will be accomplished by equipping one of the four planters with liquid fertilizer attachments. The application rate will be around 100 lbs/acre but this may be adjusted to the field's soil test. The use of starter fertilizer is primarily to enable its evaluation for future total farm use.

Supplemental nitrogen will be applied field by field on an "as needed" basis. This will be determined by visual plant symptoms and by appropriate plant tissue analysis. Application of the nutrient will be accomplished by injection into the irrigation rig at the center pivot. Four portable units consisting of a trailer, nurse-tank, injection pump and motor will administer the nutrients 10 lbs/acre at a time to maximize fertilizer usage and minimize leaching. This will be followed by a shut down of the irrigation rig for a few days following the nitrogen injection day. This practice will result in higher concentrations of nitrogen available to the plant in the upper reaches of the soil and allowing the plant sufficient time for maximum uptake of the nutrient. No more than 30 to 40 lbs/acre additional nitrogen is anticipated for any field. All other nutrients will be supplied by 1.5 to 2.0 inches/week of effluent irrigation which is anticipated as an average for all irrigated fields. Thirty to forty pounds of additional nitrogen per acre is the maximum expected. The biweekly tissue analysis will make the actual determinations of nitrogen requirements; therefore, each field will receive as is needed. We do not expect to apply too much nitrogen to the fields which are south of Apple Avenue. Thus, the actual nitrogen application could be less than 30 to 40 lbs/acre.

Harvesting will begin when appropriate grain moisture levels are reached. At least 1000 acres of corn will be harvested by a custom operator. At this time there are no unforeseen difficulties related to the harvesting operation. It should operate similar to the past years. As in 1974 the grain drying center will be utilized.

A very good local market has been developed for corn sale. To fully develop and reach its maximum potential, a means of hedging is needed other than forward contract sales. The Farm Management recommends that the commodities futures market be employed.

The look at cover crop adaptability will be enlarged this year. Not only will the rye acreage be increased, but different rates and time of seeding will be examined. There will also be an attempt at establishing quackgrass as a cover and a leguminous cover, such as Crown Vetch, may also be studied.

IX. ECONOMICS

In general, building any kind of wastewater treatment facility is expensive. If the collection and transmission systems are also included the total cost of the treatment system will increase sharply.

The common denominator in all treatment methods is the final discharge criteria of the treated wastewater. The cost of the treatment facility increases proportionately with the increase in quality of discharged water. Similarly the operational cost of the facility will increase with cleaner discharge. A biological treatment facility will cost less to construct and operate in comparison to our advanced chemical wastewater treatment plant. A land treatment method of wastewater is an alternate means of advanced treatment. Therefore, the construction as expected will be costlier than a conventional biological treatment system.

A. Construction Cost

The up-to-date estimated cost of the Muskegon land treatment system is $42,066,561.56. Table 10 shows the detailed breakdown schedule of construction costs through 1974 of the project. The project is 100% complete. Deducting the land acquisition, relocation, dislocation and moving expenses, $6,537,274.87, the net total construction, equipment and miscellaneous cost is $35,529,286.69. Further cost analysis indicates the cost per acre of the total project is $42,066,561.56 ÷ 10,800 acres = $3,895.05/acre.

Table 11 shows the schedule of irrigation spray rig costs, and the total irrigation spray system cost. The cost per acre is $347.18 and $1,168.39 respectively.

TABLE 10

COUNTY OF MUSKEGON - WASTEWATER SYSTEM

SCHEDULE OF CONSTRUCTION COSTS THROUGH 1974

Description	Costs Incurred
Land Acquisition	$ 5,371,614.17
Relocation, Dislocation, Moving Expense	1,165,660.70
Clearing, Paving and Project Fencing	1,915,027.14
6", 8", 10" Interior Drainage Pipe - Perforated Plastic (6",8") and Concrete Drain Tile (10")	2,636,155.10
Ditches, Channels and Related Structures	1,285,889.98
Irrigation Pressure and Well Discharge Piping, Electrical Distribution System	2,000,502.05
Administration Building, Chlorine Building and Related Structures	350,661.03
Observation Wells and Drainage Wells	385,538.50
Force Mains and Sewer Lines	7,881,434.75
Pumping Stations, Lift Stations, Main Station & Irrigation, etc.	3,495,116.35
Lagoons, Treatment Facilities and Related Structures	9,965,305.50
Irrigation Spray Rigs and Pads	1,353,372.30
Utility Relocation	295,468.37
Eggleston Township Access Point	137,173.95
Engineering Feasibility Study, Project Engineer, Operations Manual, and Legal and Fiscal	2,266,342.08
Capitalized Interest	880,947.67

Description	Costs Incurred
Machinery and Equipment	
Laboratory Equipment	
Farm Machinery & Equipment	
Office Furnishings & Equipment	
Radio Equipment	
Wastewater Treatment Equipment	595,969.05
Miscellaneous Construction Costs	
Inspection Related	
Pipes, Pump Station & Ditches	
Mechanical Electrical	
Buildings	84,302.80
TOTAL	$42,066,561.56

TABLE 11

COUNTY OF MUSKEGON - WASTEWATER SYSTEM

SCHEDULE OF IRRIGATION SPRAY RIG COSTS

Description	Total Irrigation Rig Cost	Total Irrigation Spray System Cost
6", 8" Interior Drainage Pipe - Perforated Plastic Pipe	$	$ 758,005.30
Interior Drainage Pipe Over 10" - Concrete Drain Tile		1,878,149.80
Irrigation Pressure Pipe and Well Discharge Piping		1,444,368.04
Electrical Distribution System	556,134.01	556,134.01
Irrigation Pumping Stations 1 and 2		437,623.06
Irrigation Spray Rigs	1,353,372.30	1,353,372.30
TOTAL	$1,909,506.31	$6,426,161.28
Number Acres Under Irrigation	5,500	5,500
Cost Per Acre	$ 347.18	$ 1,168.39

B. Operational Cost

Table 12 shows the 1974 total operational cost of the system - $2,033,831.00. The total gallonage fee will be as follows:

Total operation cost ----------		$2,033,831.00
Revenue		
1. Crop Sale -----	$367,566.00	
2. R&D Refund ----	199,739.00	
Total	$567,305.00	
		- 567,305.00
		$1,466,526.00

Gallonage Fee* $1,466,526 ÷ 10,000 mg = $146.65/mg

The estimated 1975 operational cost is shown in Table 13. The estimated operational and maintenance cost is $2,277,617. This figure includes capital expenditures of $126,300.00,

TABLE 12

COUNTY OF MUSKEGON - WASTEWATER SYSTEM

SCHEDULE OF COSTS - 1974

Direct Materials & Services	$ 975,408
Direct Labor	398,397
Overhead & Fringe	116,614
Administrative	543.412
Total	$2,033.831

*Does not include amortization, depreciation, prior operating deficit and interest.

TABLE 13

COUNTY OF MUSKEGON - WASTEWATER SYSTEM
SCHEDULE OF BUDGETED COSTS - 1975

Direct Materials & Services*	$1,504,705
Direct Labor	528,413
Overhead & Fringe	133,723
Administrative	110,826
Total	$2,277,667

*Includes capital expenditures of $71,207, leaving a net operational budget of $2,206,460.00.

Table 14 shows the irrigation spray system operating expenses. Deducting the spray operation cost from the total O&M cost on a gallonage basis, would reduce the users' rate by $19.74/mg.

$201,714 ÷ 10,220 mg = $19.74/mg

Table 15 shows the schedule of electrical KWH/costs. The estimated electrical cost is $620,851. The electrical consumption per mg is $620,851 ÷ 10,220 mg = $60.75/mg, leaving a net O&M budget of $2,206,460.00.

Total O&M Cost ---------- ------			$2,206,460.00
Revenues			
1. Crop Sales	----	$555,000 (Est.)	
2. R&D Refund	----	155,000	
3. Services	----	35,000	
Total		$745,000	
			- 745,000.00
			$1,461,460.00

Gallonage Fee - $1,461,460 ÷ 10,220 mg = $143/mg

Gallonage Fee per mg

1. 1975 Operating Budget	$143.00
2. Operating deficit of prior years	8.00
3. 1975 Depreciation (machinery & equipment only)	11.50
4. Working capital requirements	5.00
5. Interest on deficit	2.50
	$170.00/mg

TABLE 14

COUNTY OF MUSKEGON - WASTEWATER SYSTEM

IRRIGATION SPRAY SYSTEM OPERATING EXPENSE

	1974 Actual Cost	1975 Budgeted Cost
Direct Labor	$ 28,562.00	$ 37,723.00
Overhead & Fringe	9,862.00	9,182.00
Electricity*	94,830.00	154,809.00
Total	$133,254.00	$201,714.00
Acres Services	4,500.00	5,500.00
Cost per Acre	$ 29.61	$ 36.68

*Electricity KWH consumption increase of 21.3% with cost rise of 14.9%.

TABLE 15

COUNTY OF MUSKEGON - WASTEWATER SYSTEM

SCHEDULE OF ELECTRICAL KWH/COSTS

MUSKEGON SYSTEM

	1974		Estimated Budget For 1975*	
	KWH	DOLLARS	KWH	DOLLARS
Lift Stations	$11,095.475	$162,178.82	$11,119,200	$187,734
Treatment Operations	15,048,805	223,186.58	16,483,027	278,308
Irrigation Systems	6,301,595	94,830.05	8,997,748	154,809
	$32,445,875	$480,195.45	$36,599,975	$620,851**

*Electricity cost increase of 186.5%.

**1975 fuel cost adjustments are per Consumers Power Co. with their Palisades Nucleau Plant Operational in January, 1975.

Table 16 shows the schedule of 1975 estimated labor expenses. Total labor expense including fringe and overhead is $502,167, and the labor rate per MG is $49.14.

TABLE 16

COUNTY OF MUSKEGON - WASTEWATER SYSTEM
SCHEDULE OF 1975 ESTIMATED LABOR EXPENSE

	Manpower	Direct Labor & Fringe
Operations & Maintenance	16	$211,064
Spray Rig Maintenance	4	46,905
Farm Operations	8	92,517(1)
Equipment Maintenance	3	45,026
Laboratory & Monitoring	12	49,223(2)
Administrative	3	57,432
Total	46	$502,167

Annual Gallonage Flow - 10,220 Mg

Labor Rate per mg - $49.14

(1) Excludes farm manager's 75% Federal funding portion from E.P.A. Grant.

(2) Excludes 75% Federal funding portion on E.P.A. Research Grants.

X. Summary

The Muskegon County Wastewater Management System was designed to treat liquid wastewater by biological treatment in aerated lagoons and subsequently store it for the winter season, and then spray irrigate on the crop farmland during the growing season. The land treatment "living filter" process is providing the advance treatment for the wastewater.

The design objectives for the Muskegon County Wastewater Treatment System are as follows:

1. The abatement of municipal and industrial wastewater discharge into the county's already polluted surface water.
2. Effectively renovating industrial and domestic wastewater into cleaner water before discharging into the surface water.
3. Reclaiming marginal non-productive land into productive agricultural land.
4. Stimulating county economical development by increased tourism and industrial expansion.
5. Creating a county-wide progressive and cooperative working atmosphere within the municipalities.

The system is designed to be capable of treating 42 MGD of combined industrial and domestic liquid waste by 1992. The results and experience of the 1974 operation indicate that the system is effectively treating wastewater and renovating cleaner water. The surface water bodies are receiving a higher quality of treated water.

During the 1974 corn growing season it was demonstrated that crops can be grown effectively in sandy soil conditions and under heavy application rates of treated liquid waste. The indications are that as the field and soil conditions improve, the crop yield will also improve substantially.

By research and development it has been found that the system is over-designed. It is capable of treating twice the amount of the present 28 MGP flow capacity wastewater. The research and development program has also demonstrated that the system can be operated much more economically by conserving energy.

Systems of this magnitude and environmental significance require optimum consideration and critical management. Complete systems analysis is required as a management tool for maximum cost effectiveness versus treatment and utilization of nutrients by irrigation schedules compatible with crop requirements and land consideration.

The 1974 operations demonstrated some temporary start-up problems. These problems were mainly the irrigation segment of the project. The following is a brief explanation and a list of the main problem areas:

1. Due to high water levels in the storage lagoons (one year of treated water), wind storms and ice cover, damaged less than 10% of total dike area. The damages were repaired in the fall of 1974. This year there are no indications of major damages.
2. Breaks in irrigation pressure pipes. The reasons for these breaks are not certain yet and are under investigation. At the present time all pressure pipes are under operational conditions.
3. Faults in the electrical cables caused 16 rigs to be inoperable towards the end of the 1974 irrigation season. Some faults are attributed to pin holes and the reasons for these failures are under investigation. The faulty cables are currently under repair.
4. Reduced organic and inorganic sulfur compounds emanating from the influent caused some nuisance to the surrounding area. Most of the odor from these reduced sulfur compounds has been eliminated. The intermittent emanation is under investigation currently and is expected to be resolved.

The construction cost of the total system is $42.1 million. The operational budget for 1975 is $2,206,460.00, and the gallonage fee for the users is $170/Mg. Included in this fee are operational and maintenance costs, amortization, depreciation, prior operational deficits, interest, and working capital requirements.

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